Alternative Definitions for the Grade Factor of Broken Corn and Foreign Material

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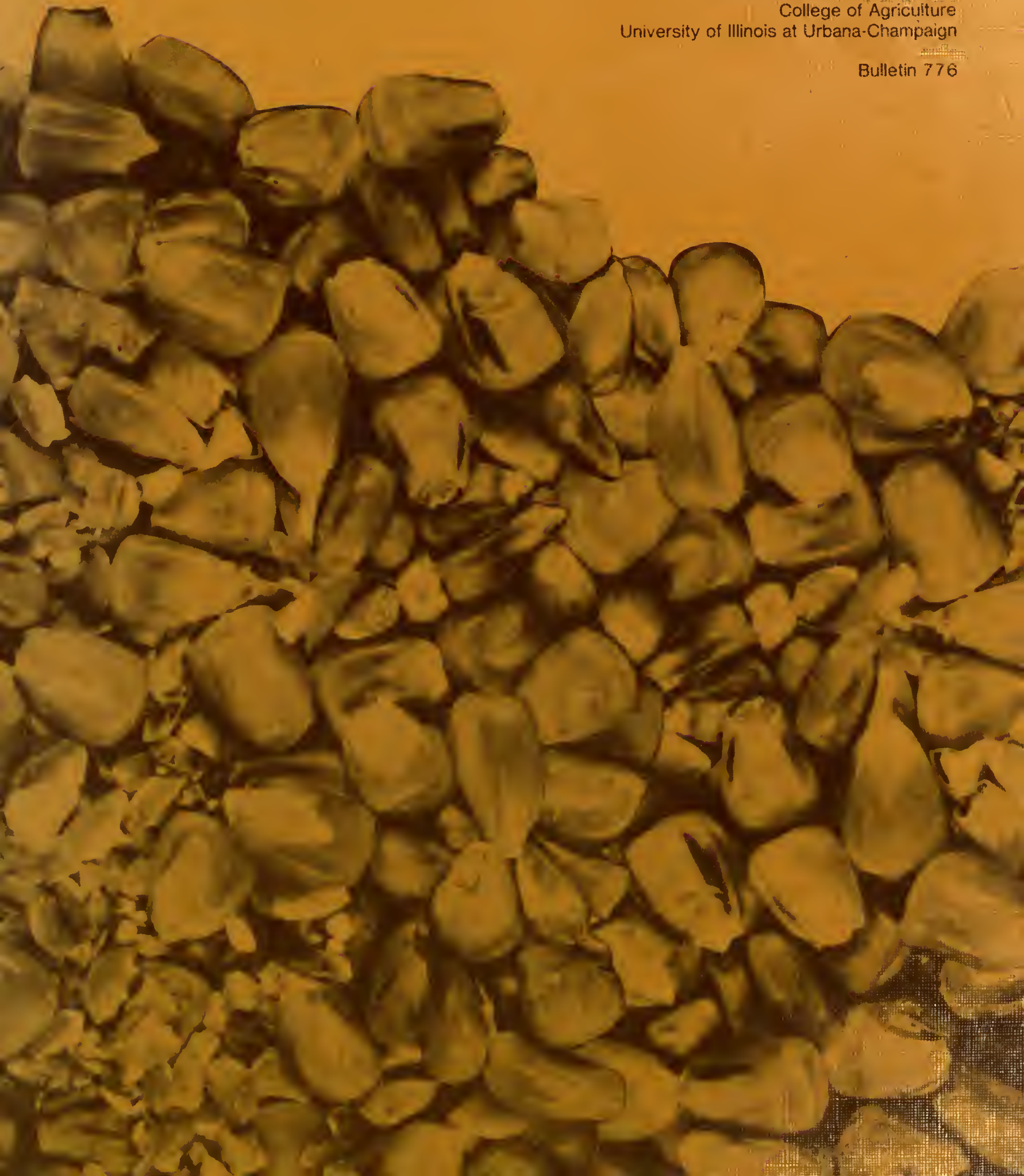

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Abstract

The purpose of the research reported in this publication was to evaluate the current definition of the grade factor for broken corn and foreign material (BCFM) and to examine alternative definitions based on various sizes of screens. The data were obtained through analysis of 1,080 samples of corn from Illinois elevators. The data show that the 12/64-inch round-hole sieve currently used does not result in maximum differentiation between corn and BCFM since much of the material passing through the sieve is broken corn. Other sieve sizes would increase the contrast between corn and BCFM on physical and chemical properties, although in this research none of the sieve sizes clearly differentiated between corn and BCFM on all properties.

To improve the information provided by the BCFM factor in the corn standards, any revision of the factor must involve more than just a change in sieve size. It must also include a redefinition of foreign material, alteration of the maximum allowances for each grade, and development of some means of identifying broken kernels. In addition, these revisions must take into account the requirements of processors, feeders, and merchandisers. This study provides data on which an evaluation of the alternatives can be based.

Keywords: corn grades, corn quality, grades and standards

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Introduction

The official U.S. Department of Agriculture (USDA) grade standards for corn include a factor identified as broken corn and foreign material (BCFM), which is defined as "kernels and pieces of kernels of corn and all matter other than corn which will pass readily through a 12/64-inch sieve, and all matter other than corn which remains in the sieved sample." The implicit, if not explicit, justification for including BCFM as a factor for determining grade is that material smaller than 12/64 inch is of less value than whole kernels and larger broken pieces and that its presence in a sample reduces the value.

In establishing the grade of a sample, the amount of fine material (often referred to as corn screenings) is combined with the amount of larger foreign material such as cobs and pieces of plants, and all types of BCFM are treated as having equal value in establishing price discounts. Under the harvesting conditions of the early 1900s when the standards were first published, the primary content of screenings may well have been dirt and weed seeds, especially at the time the corn was delivered from the farm. But with the development of field shelling, artificial drying, and high-speed handling equipment, the content of screenings has changed until most of the material called BCFM consists of pieces of broken corn. As the corn moves through the market channels, the proportion of BCFM composed of matter other than corn decreases. In addition, the broad definition does not differentiate between potentially harmful materials such as jimsonweed seeds, materials such as pieces of cob that are innocuous but of little value, and pieces of corn that are similar in value to whole kernels. The popular reference to BCFM as foreign material therefore does not give an accurate indication of the value and composition of the material against which discounts are often levied.

The way in which numerical standards are used in determining discounts leads to an additional problem in using BCFM content as a grade factor. For each numerical grade, a maximum allowable BCFM content is specified (Table 1). Corn is priced on the basis of No. 2 grade, and discounts are applied if the BCFM content is greater than 3 percent. However, a premium is almost never offered if the BCFM content is less than 3 percent. Therefore, the system provides a strong economic incentive to add screenings to any grain containing less than 3 percent BCFM and to remove screenings if it contains more. Since each handling generally increases the breakage and thus the BCFM content, the multiple transfers that normally take place as corn moves from the farm to its final destination may result in successive cleaning and blending by several different firms, adding to costs and aggravating the problem of broken corn. Previous research has shown that in many cases screenings are removed and portions returned to the grain several times before the corn reaches its final destination.[1]

This system also encourages farmers to adjust their combining, drying, and handling practices so as to approach the 3 percent BCFM limit if by doing so they can increase the total weight delivered to the elevator or decrease their harvesting costs. Although these practices do not add to the value of the corn, they increase the farmers' returns per acre because corn combined with up to 3 percent BCFM can be sold to an elevator at the same price as corn with no FM.

The appropriate screen size for determining BCFM content was the subject of research and debate in the 1920s[2,3] and again in 1937.[4] Unfortunately, no record of the re-

1. L. Hill, M. Paulsen, and M. Early, *Corn Quality: Changes During Export,* Illinois Agricultural Experiment Station Special Publication No. 58 (Urbana, Illinois, 1979), pp. 15-16.

2. Correspondence from O.F. Phillips, Chairman, Board of Review, Office of Markets and Rural Organization, U.S. Department of Agriculture, Washington, D.C., to H.J. Besley, Grain Division, Bureau of Markets, Chicago, January 20, 1920 (from USDA files).

3. Correspondence from O.F. Phillips to H.J. Besley, March 30, 1921 (from USDA files).

4. "Research Observations of the Grade Factor, 'Cracked Corn and Foreign Material,'" April 16, 1937, Bureau of Agricultural Economics, USDA, Washington, D.C. (unpublished document from USDA files).

Table 1. Grades and Grade Requirements for Corn

Grade	Min. test weight per bushel, pounds	Maximum limits of: Moisture, percent	Broken corn & foreign material, percent	Damaged kernels: Total, percent	Damaged kernels: Heat-damaged kernels, percent
No. 1.......	56.0	14.0	2.0	3.0	0.1
No. 2.......	54.0	15.5	3.0	5.0	0.2
No. 3.......	52.0	17.5	4.0	7.0	0.5
No. 4.......	49.0	20.0	5.0	10.0	1.0
No. 5.......	46.0	23.0	7.0	15.0	3.0
U.S. Sample grade	U.S. Sample grade shall be corn which does not meet the requirements for any of the grades from U.S. No. 1 to U.S No. 5, inclusive; or which contains stones; or which is musty, or sour, or heating, or which has any commercially objectionable foreign odor; or which is otherwise of distinctly low quality.				

Source: The Official United States Standards for Grain, Federal Grain Inspection Service, U.S. Department of Agriculture.

search results was preserved. From the information contained in available documents, it appears that the grain trade objected to the use of the 14/64-inch screen specified in the Grain Standards Act of 1916 because it resulted in large amounts of broken corn and small kernels being classified as BCFM.

The USDA's 1937 report states that "the first corn standards promulgated by the Department in 1913 were permissive in character and contained two special limitations for 'cracked corn and foreign material,' in the application of which the 16/64-inch round-hole perforation sieve was used to remove large pieces of broken kernels and the 9/64-inch round-hole perforation sieve was used to remove fine pieces and mealy material. Widespread public opposition arose to the use of two sieves, and when the Federal corn standards were promulgated under the United States Grain Standards Act in 1916, they specified only one sieve for the determination of cracked corn and foreign material, namely, the 14/64-inch sieve. This sieve was used from 1916 to 1921 and was discarded in 1921 as a result of representations made to the Department that its use resulted in lowering the grade of much kiln-dried corn which reasonably met consumers' demands and warehouse requirements with respect to this grade factor. For this reason the 12/64-inch sieve was adopted in 1921 and has been in use for 16 years."[5]

The writers quoted in these documents state that the trade's primary reason for seeking a change in screen size was that the grade of good corn was being lowered unjustifiably on the basis of a factor that did not accurately measure consumers' demands. The description of USDA research on screen size in the 1937 document indicates that although several screen sizes were evaluated the 12/64-inch screen was the only one considered feasible. If smaller screens were used, the BCFM content of No. 2 corn would consist mostly of dust and fine material; broken kernels previously classed as BCFM, using the larger screen, would be classified as whole corn, using a smaller screen. Cleaning would not be required unless more than 3 percent of the sample passed through the 8/64- or 6/64-inch screen. The quality of No. 2 corn would therefore be lowered by using a smaller screen.

This conclusion is valid only if the grade limits remained unchanged. Although the assumptions were not clearly stated in the 1937 report, it is implied that the change in screen size would not be accompanied by a change in the limits for BCFM content. Consequently, the effect of a smaller screen would have been to liberalize the standards, increase the amount of dust and meal in No. 2 corn, and increase the amount of large broken kernels accepted as whole corn above the screen. The evaluation criteria implicit in the report are (1) that the percentage of samples falling into each of the grades should remain unchanged and (2) that the amount of meal and dust that would be left in the corn as part of the 3 percent allowable BCFM content should not be increased. The reports do not address the relative value of BCFM versus corn, nor do they provide a justification for the differentiation.

Oscar Phillips, Chairman, Board of Review, Federal Grain Inspection Service, USDA, was aware of the economic implications of alternative definitions of BCFM in his statement that "changing the sieves . . . would result in raising the grade in many instances, and justly so, as it is *only the finer, smaller particles of cracked corn that are objectionable to the trade.*"[6]

This review of past concerns about the "best" screen size for defining BCFM provides the point of departure for the research reported in this publication. The objective of the research was to evaluate the effects of alternative screen sizes on the value of screenings, on the chemical and physical properties of material above and below the BCFM screen, and on the distribution of samples (among the five numerical grades for corn) at the farm and the elevator. Although changes in screen sizes have been proposed in the past, major disruptions in the pricing and grading of corn in the market are likely to occur unless these changes are accompanied by simultaneous changes in the grade limits. This study examines the issue of alternative screen sizes and simultaneous changes in the standards and considers the possible response by grain marketing firms.

Data Collection

The data for the study were obtained from two sources: a questionnaire mailed to all Illinois elevators in 1976 and 1,080 samples of corn collected from country elevators, inland subterminals, and river elevators in Illinois. The 1976 survey of Illinois elevators was conducted primarily to determine the merchandising practices used for corn screenings, to identify grading and discount procedures, and to estimate prices received by elevators for the excess corn screenings removed from the corn and sold separately. A questionnaire was mailed to a complete list of Illinois elevators (1,437). The 285 responses were assumed to be representative of the entire population for those variables of primary interest.

The second source of data was samples of corn collected from randomly selected Illinois elevators in

5. "Research Observations," April 16, 1937 (from USDA files).

6. Phillips to Besley, January 20, 1920 (from USDA files).

1976 and 1977. The state was divided into four regions representing different production and marketing characteristics (Figure 1). In each region five country elevators and five subterminal elevators (river and inland) were selected to provide ten samples of inbound corn delivered from trucks and ten samples of outbound corn taken from the load-out stream. In district 3 the small number of subterminals and the lack of sufficient corn receipts following harvest precluded collection of the full set of samples. Subterminal samples were therefore limited to the other three regions. In region 2 one of the five elevators was unable to provide a complete set of samples and was deleted from the 1976 sample collection. In areas near the river, the subterminal category included river elevators. In landlocked regions the subterminals were elevators sometimes referred to as *inland terminals.*

In 1977, cost limitations made it necessary to reduce the sample size. Since geographical differences did not appear to be important in the 1976 data, the 1977 sample was not stratified by geographical location. Ten country and ten subterminal elevators were selected to represent the grain deliveries for the state (see Figure 1). Insofar as possible, the 1977 elevators were selected from the set for 1976. Some substitutions were necessary either because the elevator refused to provide samples or because the seasonality of grain deliveries and shipments did not coincide with the availability of personnel to collect the samples.

Each of the elevators agreed to provide ten samples of inbound corn as it was unloaded from trucks and ten samples of outbound corn as it was loaded into rail cars, barges, or trucks. Samples from country elevators therefore consisted of inbound corn from farm trucks and outbound corn destined for other elevators. Subterminal elevators (river and inland) provided inbound samples from country elevator deliveries and outbound samples from their load-out spouts or belts. Most samples were collected by research assistants sent to the elevator, although unpredictable receiving and shipping schedules sometimes made it necessary to permit elevator personnel to take samples according to instructions from the researchers. Samples from the 1976 crop were taken between January and August, 1977. Samples from the 1977 crop were taken between October, 1977, and August, 1978. The total number of samples collected is shown in Table 2.

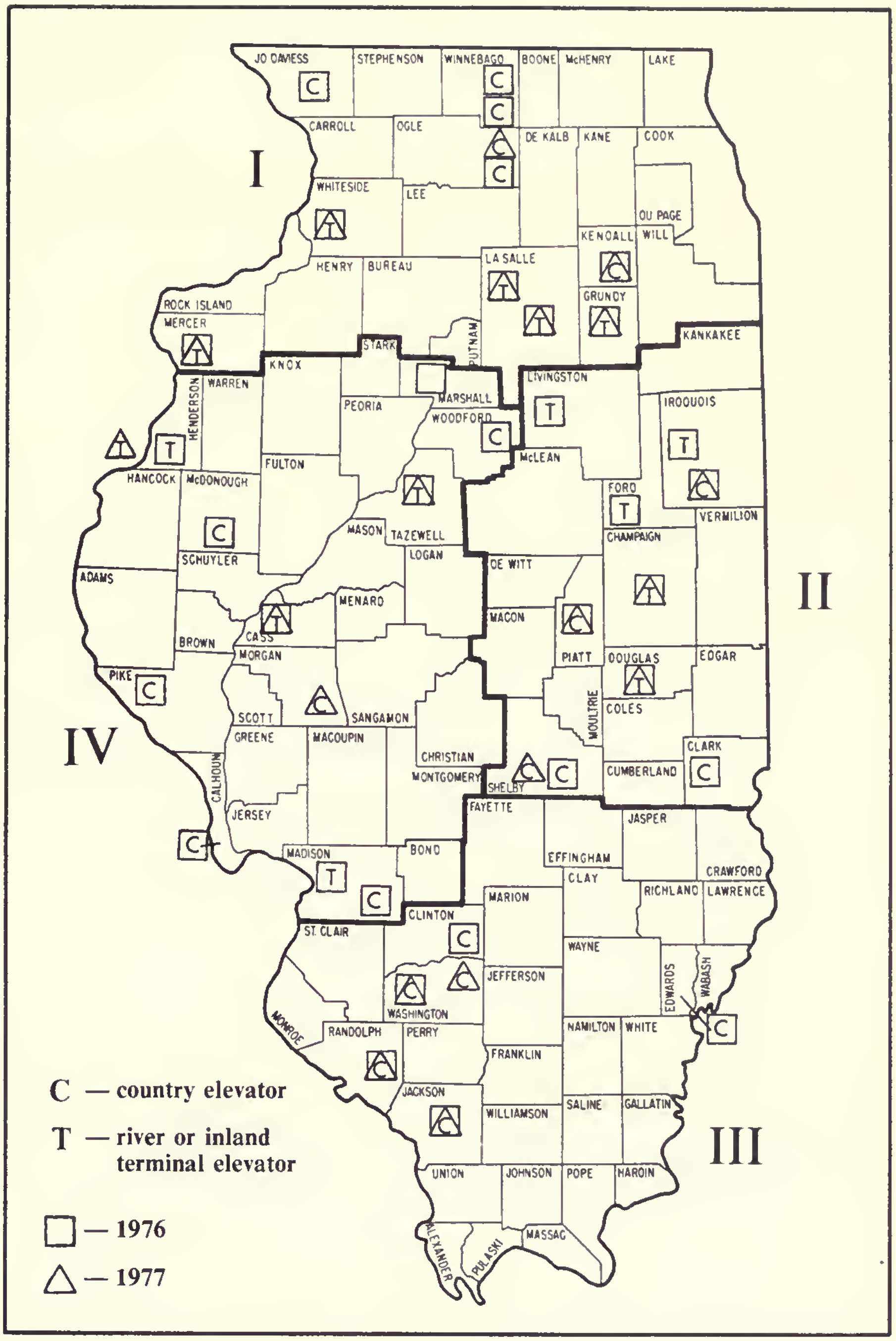

Figure 1. Location of elevators that provided corn samples from the 1976 and 1977 crops.

Table 2. **Number of Corn Samples Collected From Illinois Country Elevators and Subterminal Elevators in 1976 and 1977**

	Country elevators			Subterminal elevators		
	Number	Number of samples		Number	Number of samples	
Region	of firms	Receipts	Shipments	of firms	Receipts	Shipments
1976						
1	5	50	50	5	50	50
2	4	40	40	5	50	50
3	5	50	50	0	0	0
4	5	50	50	5	50	50
State total	19	190	190	15	150	150
1977						
1	2	20	20	5	50	50
2	3	30	30	2	20	20
3	4	40	40	0	0	0
4	1	10	10	3	30	30
State total	10	100	100	10	100	100

Each sample was divided into seven size categories, using six different screens in a Carter-Day dockage machine. Each particle size was then analyzed to determine what proportion of the material was corn, corn by-products (such as cobs and chaff), weed seeds, other grains, and inert materials or dust. Samples of each particle size were also sent to a commercial laboratory to determine the percentage of crude protein, fat, fiber, ash, and nitrogen-free extract. The energy content in kilocalories per gram was calculated for nonruminant rations. All particle sizes were individually tested with an ultraviolet light for bright greenish yellow fluorescence (BGYF). If any particle size showed a positive response to the BGYF test, the entire sample (all particle sizes) was sent to the USDA's Northern Regional Research Center at Peoria, Illinois, to determine if aflatoxin was present and, if so, the kind and quantity.

Composites of all country elevator inbound samples for each particle size and a second set of composites for all outbound samples were equilibrated to approximately 18 percent moisture and placed in an open beaker in a growth chamber at 80° F. dry bulb temperature and 80 percent relative humidity. Samples from terminal elevators were prepared in a similar manner. At weekly intervals, over a period of 28 weeks, each sample was scored on a scale from 1 to 5 for mold growth. This scale was converted to a percentage of material molded to accommodate fractional values in the weekly averages.

These results were analyzed to provide information on possible changes in the definition of the BCFM factor in current corn standards. There are several alternatives to the present procedures for defining BCFM and establishing limits. Evaluation of the alternatives requires an understanding of the limitations of the present standards and procedures for determining BCFM.

Problems With the Present Definition of BCFM

There are three basic problems with the BCFM grade factor used in the present corn standards:

- Foreign material (matter other than corn) is assigned the same relative value as broken pieces of corn.
- Numerical standards with maximum allowances for BCFM content encourage the blending of screenings (including dust) into any corn containing less than the maximum BCFM content permitted in the grade of corn being sold.
- The 12/64-inch screen used to identify BCFM does not result in maximum differences between corn and BCFM.

Differentiation between broken corn and foreign material

Most domestic and foreign buyers recognize that BCFM is primarily corn and hence has feeding value. Domestic feeders and feed manufacturers frequently buy screenings to use as feed. Even corn dust is often pelleted and used for feed. Excess screenings at starch plants in Europe are sold to feed firms or added to feed by-products. The screenings clearly have value, and the price of screenings relative to the price of corn indicates the value placed by the market on the average quality of screenings removed from the market channel. This price is influenced by the nutritive value of the screenings, the price of corn, the local demand and supply conditions, the proximity of the source to users, and the storability of the screenings. Prices will therefore vary with time and location.

The 1977 survey of Illinois country elevators provided average monthly prices for corn screenings sold by Illinois elevators (Table 3). The unweighted annual average price of screenings was $66.75 per ton, ranging from a low of $61.83 in November, 1975, to a high of

$70.96 in July, 1976. The price of screenings as a percentage of the price of corn varied from 69 to 77 percent, with an annual average of 72 percent. Data from a limited number of starch plants in Europe show that screenings are valued slightly lower relative to the price of corn than in the United States. The starch plants in Europe generally purchase No. 3 corn rather than No. 2. The average price for "dust and brokens" (screenings) was about 60 percent of the delivered price for No. 3 U.S. yellow corn. However, adjustments for the starch production refund and for exchange rates in the European Community add to the value of dust and brokens, so the realized price ratio is higher than 60 percent.

Quantitative measures of the chemical content and physical properties of BCFM were obtained through an analysis of the 1,080 samples of corn collected at country elevators and subterminals in Illinois. Table 4 shows that in the 1976 and 1977 crops together, 83.4 percent of the material passing through a 12/64-inch screen was corn at the time the grain was delivered to the country elevators from the farm. This amount increased to 87.9 percent when the grain was outbound from the country elevator, 88.9 percent when inbound to the subterminal, and 90.0 percent when outbound from the subterminal.

In these samples the BCFM was composed mostly of broken corn and was therefore of higher value than foreign material consisting of inert materials, corn by-products, dirt, and weed seeds. Combining broken corn and foreign material into one category misrepresents its value and leaves the buyer unsure of what he or she will receive. Individual samples of BCFM (material passing through the 12/64-inch screen) contained as much as 30 percent noncorn materials and as little as 3 percent. Official grade standards assure the buyer only of the maximum percentage of BCFM; there is no indication of whether the BCFM will consist mostly of dust and inert material or mostly corn pieces.

If the material classified as BCFM is primarily corn pieces smaller than 12/64 inch, it is economically important to determine if whole corn, broken corn larger than 12/64 inch, and BCFM differ significantly in value. Since the market establishes a discount system that corresponds to the grade limits for BCFM, it is implicitly assumed that corn pieces larger than 12/64 inch are of greater value than smaller pieces. Further, since the price is established for No. 2 corn with discounts only if BCFM exceeds 3 percent, it is implied that the first 3 percent of BCFM is equal in value to corn and requires no discount but that additional quantities of BCFM are considerably less valuable than the corn and thus do require a discount.

Table 3. Average Monthly Illinois Prices and Discounts for Corn Screenings, October, 1975, Through September, 1976

Month	Number of firms responding	Avg. monthly price of: Screenings	Avg. monthly price of: Corn	Screenings discount	Price of screenings as a percentage of corn price
		-----dollars per ton-----			
October	36	63.44	91.77	28.33	69
November	36	61.83	83.56	21.73	74
December	37	65.11	84.63	19.52	77
January	42	64.86	88.56	23.70	73
February	38	66.29	90.70	24.41	73
March	43	67.42	91.42	24.00	74
April	28	67.07	89.63	22.56	75
May	25	68.96	96.05	27.09	72
June	24	69.58	100.35	30.77	69
July	25	70.96	102.84	31.88	69
August	21	68.71	94.27	25.56	73
September	25	66.88	94.63	27.75	71
Annual avg.		66.75	92.37	25.61	72

Source: Bruce Brooks, "An Analysis of BCFM in Corn and the Market for Corn Screenings," in *1977 Corn Quality Conference*, proceedings, Department of Agricultural Economics, University of Illinois (Urbana, February, 1978).

Table 4. Physical Properties of Materials Passing Through a 12/64-Inch Round-Hole Screen, Illinois, 1976-1977 Average

	Country elevator Receipts	Country elevator Shipments	Terminal elevator Receipts	Terminal elevator Shipments	All samples
	percent of total sample weight				
Corn	83.4	87.9	88.9	90.0	87.4
	(14.4)[a]	(9.6)	(10.1)	(8.0)	(11.2)
Dust & inert mat.	0.7	0.4	...[b]	0.2	0.3
	(2.1)	(1.4)	(0.2)	(1.4)	(1.5)
Weed seeds	3.4	1.4	1.2	0.6	1.7
	(7.6)	(3.2)	(5.0)	(1.6)	(5.0)
Corn by-products	12.6	10.3	9.8	9.2	10.55
	(11.9)	(9.4)	(9.2)	(7.6)	(9.8)

[a] The values in parentheses are standard deviations.
[b] Less than 0.1 percent.

Blending of BCFM

The allowance of 3 percent BCFM in No. 2 corn gives grain handlers an economic incentive to make every shipment of corn contain as close to 3 percent as the supply of dust and screenings and the blending capabilities of the plant will allow. Putting screenings back into

the grain stream adds to the cost of blending and cleaning and increases breakage. In addition, there is growing concern that this practice increases the danger of dust explosions. At the International Symposium on Grain Elevator Explosions, several speakers identified the removal of grain dust from the grain as a necessary step in reducing the danger of elevator explosions.[7] Investments in control of air pollution resulting from grain dust are becoming an important cause of increasing elevator operating costs. Yet, under the present grain standards, grain handlers are penalized economically for removing the dust (unless BCFM exceeds the grade limit) since removal of the dust reduces the weight of the grain.

Some industry spokesmen and government agencies have recommended removing grain dust and prohibiting its reintroduction into the grain stream.[8] This measure will be resisted by operating management so long as the economic incentives for blending outweigh the dangers and costs of explosions. The added cost of blending to the contract limit on BCFM is not offset by added value at the destination, especially if it is purchased by a corn dry miller. The extra BCFM seldom benefits the miller and must be removed and sold for considerably less than the purchase price.

Screen size

The 12/64-inch, round-hole screen currently used for defining BCFM replaced the 14/64-inch screen in October, 1921. The scientific basis for this change is not stated in any published work; it is stated only that the change was made.[9] Since particles smaller than 12/64 inch receive significant price discounts (see Table 3), one would expect the physical or chemical characteristics of the two particle sizes to be significantly different. Most of the reasons given for the reduced value of screenings (such as handling problems and restricted airflow) are related either to the chemical or physical properties of the two particle sizes.

However, analysis of corn and corn screenings of various particle sizes fails to show significant differences in the chemical and physical properties of particles larger or smaller than 12/64 inch. As shown in Table 5, 97.2 to 100 percent of the material in the top three size categories was corn. Except for the percentage of whole kernels, the physical and chemical properties of material larger than 12/64 inch are indistinguishable from those of material passing through the 12/64-inch screen. Nor does the 12/64-inch screen uniformly or consistently separate whole kernels. In some samples of receipts at terminal elevators, the material passing over the 12/64-inch screen contained as little as 86 percent whole kernels. On the average, the percentage of whole kernels is reduced with each successive handling.

Although the significance of each of these problems has been documented, few data are available to aid in finding solutions. The analysis of the 1,080 samples collected from country and subterminal elevators in Illinois following the 1976 and 1977 harvest provides data for evaluating alternative definitions of BCFM in the corn standards.

7. Robert M. Frye, "The FAR-MAR-CO Approach to the Prevention of Grain Dust Explosions," p. 46; A. Neal Fugett, "Elevator Explosions," p. 47; Leland Bartelt, "Insurance Industry Views," p. 59; A.S. Townsend, "Grain Dust Explosions: The Time Has Come to Bite the Bullet," p. 61; In *Proceedings of the International Symposium on Grain Elevator Explosions,* Vol. 2, National Academy of Sciences, National Research Council, National Materials Advisory Board Publication No. 352-2 (Washington, D.C., 1978).

8. Ibid.

9. *Historical Review of Changes in the Grain Standards of the United States,* U.S. Department of Agriculture, Federal Grain Inspection Service Publication No. 5 (Washington, D.C., 1980), p. 10.

Description of the Samples

When the sample material from the 1976 and 1977 crops was separated by size regardless of its physical characteristics, the greatest proportion of every sample was retained on the 15/64-inch screen. Decreasing percentages were retained on each smaller screen down to the 4.5/64-inch screen (Table 6). For all samples the average amount of sample on the 15/16-inch screen was over 95 percent. Between country elevator receipts and terminal elevator shipments, additional handling reduced the percentage of material retained on the 15/64-inch screen from 97.08 percent to 95.28 percent in the combined 1976-1977 results. Handling also increased the amount of the finest materials from 0.14 to 0.32 percent of the weight in the samples.

According to these data, less than 2 percent of each sample collected from country elevator receipts passed through the 12/64-inch screen. The actual content of BCFM in corn delivered from the farm was below the maximum for No. 1 corn (2.0 percent). Shipments from the terminal elevator contained 2.59 percent BCFM. This figure reflects the increased breakage that results from handling and, more important, illustrates that before selling corn most elevators blend or clean it to the 3 percent BCFM limit for No. 2 corn. Not all terminal elevators have facilities for blending, and some corn is shipped at less than 3 percent BCFM, reducing the average to 2.59.

The distribution of the samples among the seven different particle

sizes was nearly identical for country elevator shipments and subterminal elevator receipts. Most of the subterminal elevator receipts came directly from country elevators, but were not matched with the country elevator samples. The similarity of the samples is additional evidence that both were representative.

The standard deviations associated with each particle size did not show any relationship with the point in the market channel. There is no evidence that the quality of the grain was less uniform at the subterminal than it was at the country elevator. The smaller screens had a lower standard deviation primarily because the average BCFM passing through them was smaller than that passing through the larger screens.

Study Results

This section analyzes the physical and chemical properties of the seven sizes of particles in samples collected from the 1976 and 1977 crops. Although this analysis reveals relationships between these properties and screen size, it produces no clear, simple solution to the problems stated above.

Statistical tests comparing the characteristics of the samples obtained in 1976 with those obtained in 1977 showed very few significant differences. The two sets of data were therefore combined and treated as a single set of data in some of the analyses and tables in this publication to reduce the quantity of tabular material.

Chemical properties

The relationships between the chemical properties and particle size for the 1976 and 1977 crops are shown in Figures 2 through 6. In general, the fat content decreased as the particle size decreased for both years (Figure 2). In 1976, the fat content decreased from 4.66 percent in the material larger than 15/64 inch to 2.64 percent in material passing through the 4.5/64-inch screen. In 1977, the pattern was quite similar, with fat content decreasing from 4.29 percent to 2.21 percent as particle size decreased from larger than 15/64 to smaller than 4.5/64 inch. The differences among the three smallest size categories were not significant for either 1976 or 1977. However, material in the three smallest categories was significantly lower in fat content than material in the other four categories for both years. Val-

Table 5. Physical Properties of Corn Samples, Illinois, 1976 and 1977 Crops

	Particle size groups[a]						
	Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
				percent			
1976							
Country elevator receipts							
Corn	100	97.82	93.20	89.06	83.84	78.87	61.92
Dust & inert mat.	0	0.00	0.08	0.19	1.27	1.98	0.93
Weed seeds	0	0.15	0.83	1.81	4.20	3.17	3.10
Corn by-products	0	2.03	6.10	8.94	10.74	15.92	34.05
Country elevator shipments							
Corn	100	97.91	95.28	89.33	87.57	82.83	74.33
Dust & inert mat.	0	0.00	0.10	0.00	0.79	1.17	0.27
Weed seeds	0	0.66	0.48	2.80	1.60	0.63	0.29
Corn by-products	0	1.42	4.14	7.88	10.04	15.37	25.11
Subterminal elevator receipts							
Corn	100	98.41	96.32	90.38	86.89	84.14	75.17
Dust & inert mat.	0	0.15	0.00	0.00	0.00	0.00	0.00
Weed seeds	0	0.05	0.44	3.93	3.13	0.00	0.74
Corn by-products	0	1.39	3.24	5.69	9.98	15.86	24.09
Subterminal elevator shipments							
Corn	100	98.54	96.77	93.25	89.45	86.12	79.63
Dust & inert mat.	0	0.00	0.01	0.05	0.09	0.20	0.14
Weed seeds	0	0.36	0.24	1.16	1.11	0.28	0.34
Corn by-products	0	1.11	2.99	5.54	9.36	13.40	19.90
1977							
Country elevator receipts							
Corn	99.88	99.03	96.53	90.00	88.89	86.12	74.15
Dust & inert mat.	0.00	0.00	0.00	0.09	0.20	1.17	0.00
Weed seeds	0.05	0.45	2.61	7.21	5.48	1.94	6.93
Corn by-products	0.07	0.52	0.86	2.70	5.42	10.83	18.92
Country elevator shipments							
Corn	99.88	97.24	97.68	90.93	92.43	89.45	88.35
Dust & inert mat.	0.00	0.00	0.00	0.00	0.00	0.37	0.90
Weed seeds	0.05	2.28	1.43	5.71	1.86	0.25	0.38
Corn by-products	0.07	0.49	0.89	3.36	5.72	9.92	11.27
Subterminal elevator receipts							
Corn	99.92	99.11	98.09	96.78	92.33	88.15	86.79
Dust & inert mat.	0.00	0.00	0.00	0.00	0.00	0.24	0.00
Weed seeds	0.05	0.23	0.41	0.53	0.98	0.23	1.06
Corn by-products	0.03	0.66	1.49	2.69	6.69	11.37	12.16
Subterminal elevator shipments							
Corn	99.92	98.60	98.71	96.74	92.03	87.26	82.75
Dust & inert mat.	0.00	0.00	0.00	0.00	0.43	1.51	0.00
Weed seeds	0.05	1.03	0.61	0.54	0.88	0.29	0.74
Corn by-products	0.03	0.37	0.68	3.01	6.66	10.94	16.51

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.
[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

ues for the three smallest screen sizes were always lower than those for the larger screens.

Ash content was quite similar for the two crop years and changed very little as particle size was reduced from larger than 15/64 inch to smaller than 6/64 inch (Figure 3). The greatest difference in ash content was between the smallest particle size, which contained 4.94 percent ash, and the next larger particles, with 2.32 percent ash. The ash content of the whole corn was 1.39 percent.

Crude protein also differed only slightly among particle sizes down to 6/64 inch in both the 1976 and 1977 data (Figure 4). As with ash content, the percentage of protein increased in the very smallest size categories. The increase between the two smallest size categories was 1.19 percentage points in 1976 and 1.42 percentage points in 1977.

The percentage of fiber in each sample increased consistently as particle size decreased (Figure 5) in both 1976 and 1977. There was a relatively large increase between the 8/64- and 6/64-inch material. But the greatest difference was between the material passing through the 6/64-inch screen and that passing through the 4.5/64-inch screen. In both years the difference was approximately 1.7 percentage points.

There was little pattern in the relationship between nitrogen-free extract (NFE) and particle size, except in material passing through the 4.5/64-inch screen (Figure 6). The differences between adjacent screen sizes were neither large nor consistent in direction, except for a large decrease in both years between the 6/64- and 4.5/64-inch material. The NFE of the 1976 samples dropped from 80.00 to 74.26 percent; that of the 1977 samples decreased from 80.26 to 75.23 percent between those two screen sizes. The decline is related to the increased fiber and ash in the fine materials.

Table 6. Distribution of Particle Sizes in Corn Samples, Illinois, 1976-1977 Average

	Particle size groups[a]						
	Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Country elevators	*percent of total sample weight*						
Receipts........	97.08	1.68	0.52	0.33	0.17	0.08	0.14
	(1.95)[c]	(0.80)	(0.39)	(0.35)	(0.20)	(0.14)	(0.37)
Shipments......	96.08	2.07	0.77	0.49	0.26	0.12	0.21
	(1.98)	(0.82)	(0.43)	(0.32)	(0.22)	(0.13)	(0.31)
Terminal elevators							
Receipts........	96.07	1.93	0.74	0.54	0.31	0.15	0.26
	(2.48)	(0.77)	(0.51)	(0.47)	(0.32)	(0.19)	(0.45)
Shipments......	95.28	2.12	0.92	0.72	0.45	0.19	0.32
	(2.28)	(0.54)	(0.43)	(0.51)	(0.34)	(0.16)	(0.31)
All samples.....	96.17	1.94	0.73	0.51	0.29	0.13	0.23
	(2.27)	(0.76)	(0.46)	(0.44)	(0.29)	(0.16)	(0.37)

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.
[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.
[c] The values in parentheses are standard deviations.

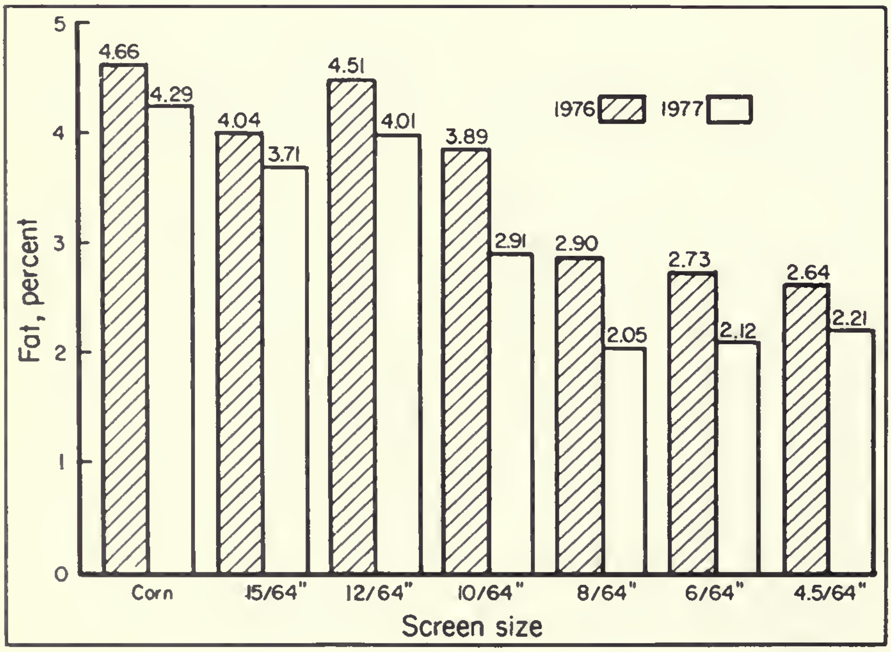

Figure 2. Relationship between particle size and fat content in corn samples from the 1976 and 1977 crops.* (See footnote on page 9.)

Physical properties

Differences in the chemical properties of the samples are partially explained by differences in their physical properties. As indicated earlier, most of the material in all particle size groups was corn. The percentage of corn varied from 100 in the material remaining on the 15/64-inch screen to 72.22 in material passing through the 4.5/64-inch screen (Figure 7). The differences between the 1976 and 1977 samples were relatively small in the larger particle sizes. However, in the smaller particle sizes considerably higher proportions of corn were found in the 1977 data than in the 1976 data. The reason for this difference is that a larger proportion

of noncorn materials, particularly weed seeds and corn by-products, were found in the 1976 crop.

Material identified as dust and inert material was seldom found in the four largest particle size groups. The quantity was always very small relative to total sample weight. The largest percentage of dust and inert material (less than 1 percent) was found in the 6/64-inch category (Figure 8). In the 1977 data, the material passing through the 8/64-inch screen contained only 0.16 percent dust and inert material, compared to 0.6 percent in the previous year's samples for that screen size.

The kind and amount of weed seeds in the samples varied with screen size. Relatively large quantities were found in the material passing through the 10/64- and 8/64-inch screens (Figure 9). Smaller amounts were found in material passing through the 6/64- and 4.5/64-inch screens. Weed seeds were present in the 1977 samples in all particle sizes except 8/64 and 6/64 inch. In the 10/64-inch size group, the percentage of weed seeds increased from 2.41 in 1976 to 3.50 in 1977.

The percentage of corn by-products (which include cobs and pieces of stalks, bees wings, and leaves) in the samples from both years increased uniformly as particle size decreased (Figure 10). In 1976, the percentage of corn by-products increased from 0 in material above the 15/64-inch screen to a maximum of 26.23 percent in material passing through the 4.5/64-inch screen. In 1977, the samples contained considerably less corn by-products but still increased from 0.05 percent in material above the 15/64-inch screen to a maximum of 14.71 percent in material passing through the 4.5/64-inch screen.

These comparisons between the 1976 and 1977 crop data show more differences in physical (corn, dust and inert material, weed seeds,

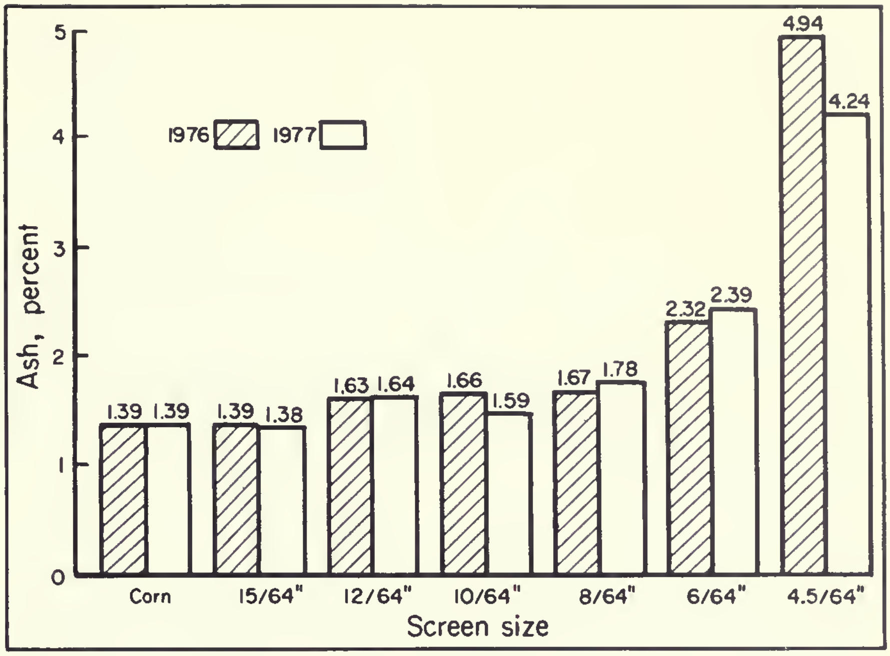

Figure 3. Relationship between particle size and ash content in corn samples from the 1976 and 1977 crops.*

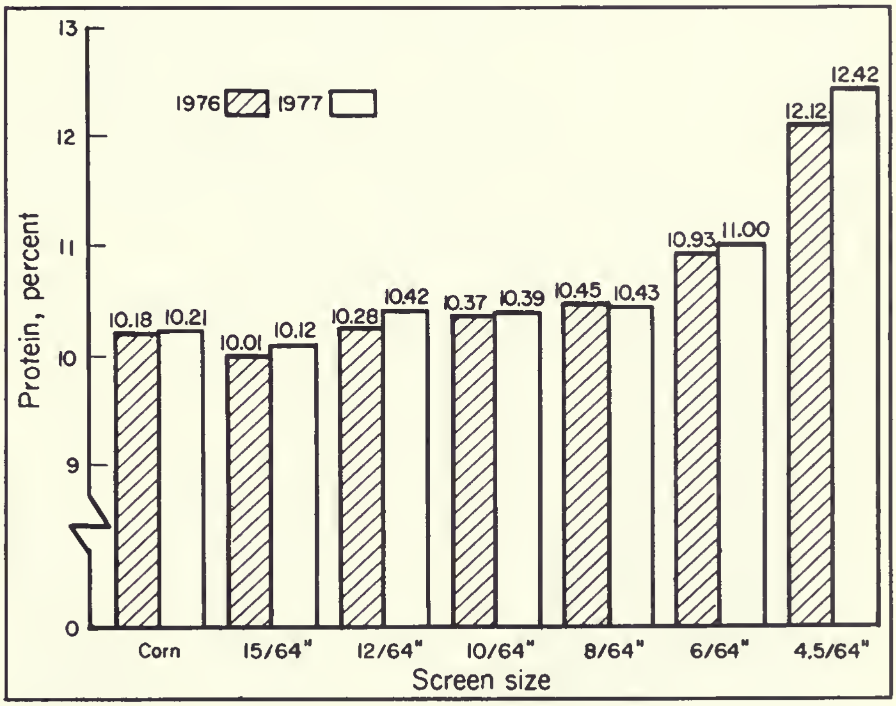

Figure 4. Relationship between particle size and crude protein in corn samples from the 1976 and 1977 crops.*

* The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen. The category *corn* includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

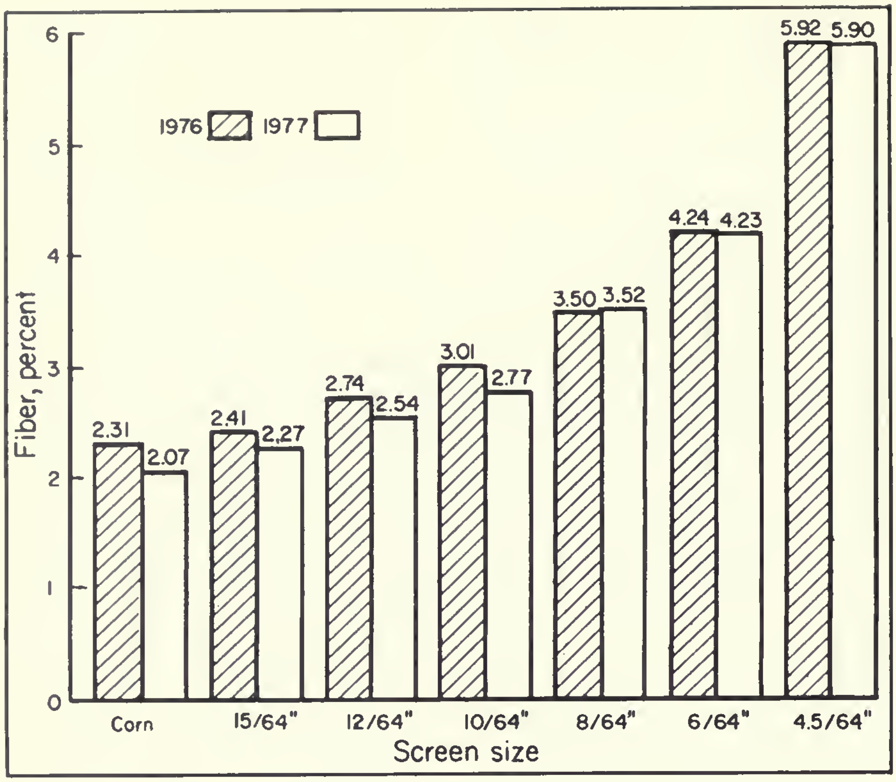

Figure 5. Relationship between particle size and fiber content in corn samples from the 1976 and 1977 crops.*

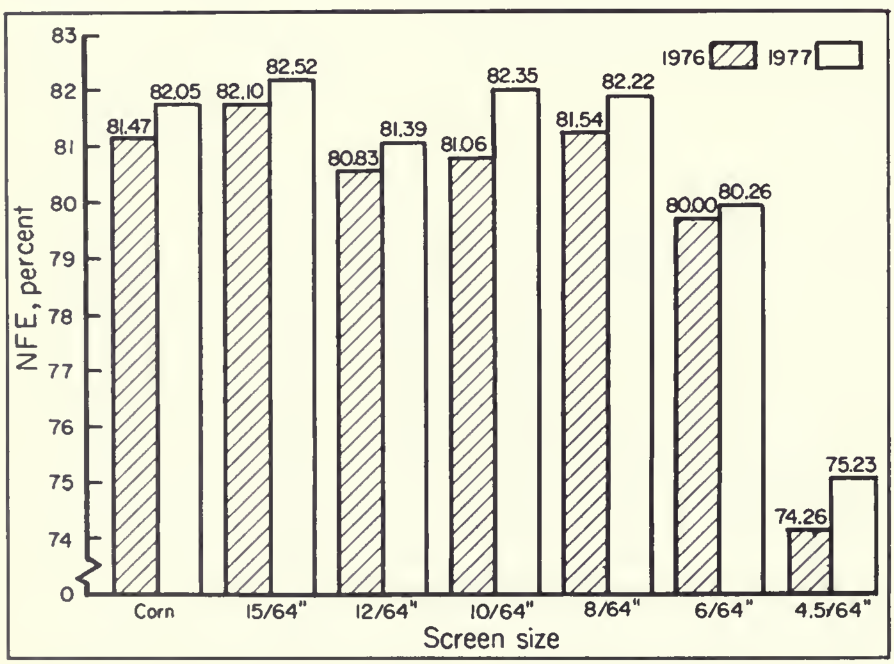

Figure 6. Relationship between particle size and nitrogen-free extract in corn samples from the 1976 and 1977 crops.*

* The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen. The category *corn* includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

and by-products) than in chemical properties (fat, ash, protein, fiber, and NFE). In the 1977 samples, the smaller particles contained a higher percentage of corn and a lower percentage of dust and inert material than the corresponding sizes of particles in the 1976 samples. In general, all particle sizes from the 1977 crop contained a higher percentage of weed seeds and a lower percentage of corn by-products than the matching particle sizes from the 1976 crop. For each particle size, the difference between years was greater in percentage of weed seed than in other chemical or physical properties. Since weed seeds vary greatly in size according to species, their distribution was determined by the kind of weeds predominating in a region.

Statistical differences

The most convenient method for comparing all samples over all properties is the Duncan's Multiple Range Test shown in Table 7. The letters *A, B. C, D, E, F* identify the size categories between which differences in the particular property were *not* significant. For example, all particle size categories that have data in row group *A* were not statistically different from one another at the 95 percent level of significance. The data for country elevator receipts for 1976 show that there is no significant difference between the three largest size categories (particles larger than 10/64 inch) on the factors of ash, protein, fiber, NFE, dust and inert material, or weed seed. In the case of ash, protein, dust and inert material, and weed seeds, there are no significant differences among the top four size categories.

Similar tests were made on 1976 data from samples obtained from country elevator shipments and subterminal elevator receipts and shipments. Only the data on country elevator samples are shown here because the differences in the pat-

terns were slight among these four sets of samples in the market channel. Similar tables for 1977 data and for all points in the market channel are given in Appendix A.

These statistical analyses provide information on which to base an evaluation of alternative screen sizes and their ability to differentiate between corn and BCFM. For example, the analysis in Table 7 indicates that material passing through the 12/64-inch screen does not differ from the next larger or next smaller material on the factors of ash, protein, fiber, NFE, dust and inert, or weed seed. In other words, changing from a 12/64-inch screen to a 10/64-inch or a 15/64-inch would have little effect on the composition of BCFM with respect to those properties.

Certain size categories were significantly different from others, but there was no uniform gradation in chemical and physical properties corresponding to the uniformly decreasing particle size categories. Fat content decreased, increased, and decreased as particle size decreased from whole corn to particles smaller than 4.5/64 inch. Nor did the content of nitrogen-free extract follow a uniform trend. The major conclusion derived from Table 7 is that neither the chemical nor physical properties of material passing through the 12/64-inch screen are unique. The material passing through the 12/64-inch screen lies between two particle sizes, most of whose characteristics are statistically indistinguishable.

The use of two screens was proposed by the Agricultural Marketing Service, USDA, in February, 1976, as a means of increasing the ability of the standards to differentiate between broken corn and noncorn foreign material. Screens sized 12/64 inch and 8/64 inch could be used to separate the sample into corn (above the 12/64-inch screen), broken corn (passing through the 12/64-inch and on top of the 8/64-inch screen), and screenings (mate-

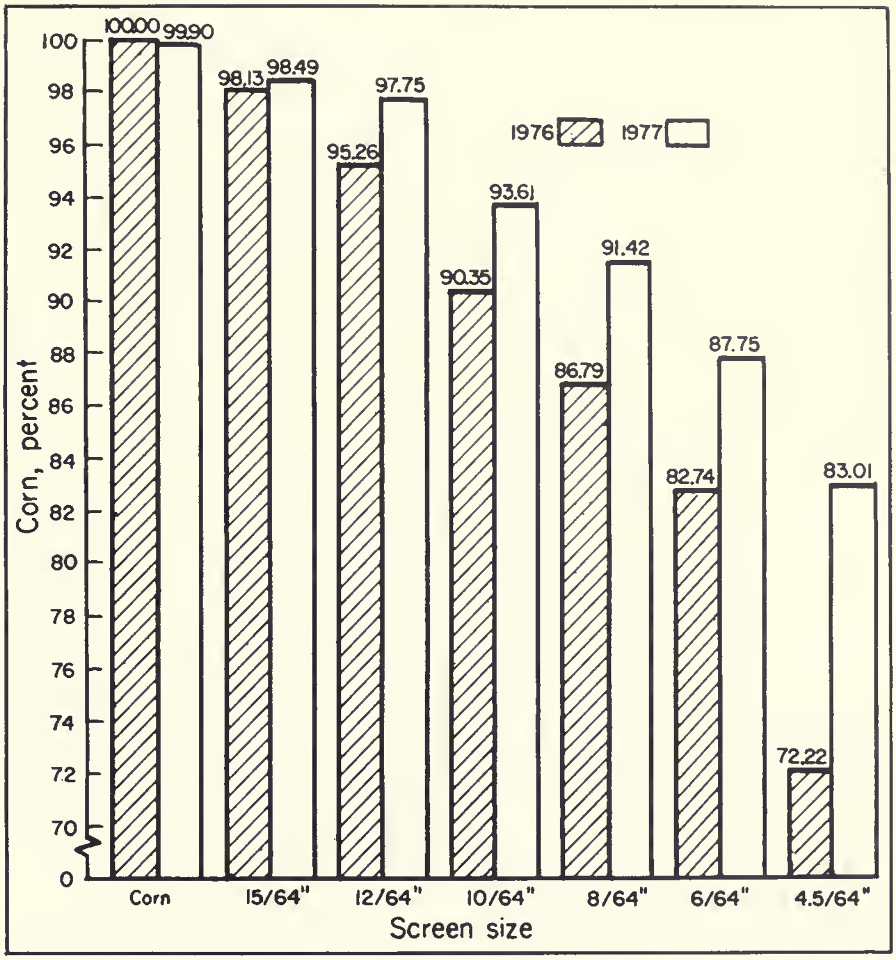

Figure 7. Relationship between particle size and percentage corn in corn samples from the 1976 and 1977 crops.* (See footnote on page 10.)

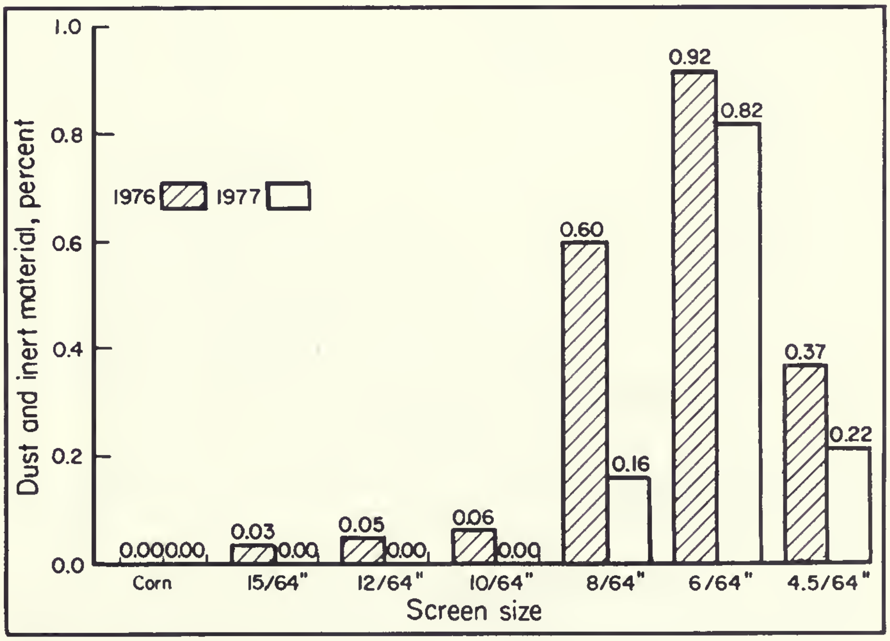

Figure 8. Relationship between particle size and percentage dust and inert material in corn samples from the 1976 and 1977 crops.*

rial passing through the 8/64-inch screen). As shown in Table 7, if this set of screens were used, the percentage of corn in each category would be significantly different. In addition, the amount of dust and inert material in the broken corn would differ significantly from that in the screenings; nearly all the dust and inert material would pass through the 8/64-inch screen. The two-screen plan would also result in significant differences in the percentage of weed seeds and corn by-products.

This plan would not be as effective in separating material into groups with clear differences in chemical properties as it would be in differentiating physical properties. There are no significant differences in any chemical properties between material passing though a 12/64-inch screen and that passing through a 15/64-inch screen. Nevertheless, the protein content of material passing through the 8/64-inch screen is significantly different from that of the larger particles.

The differences from one particle size to the next are gradual, and no one screen provides a clear-cut distinction between the chemical and physical properties of BCFM and those of corn. There were slight differences in groupings among points in the market channel and between the two crop years (Appendix A). However, the data do not point to any single screen size as the obvious choice for defining BCFM.

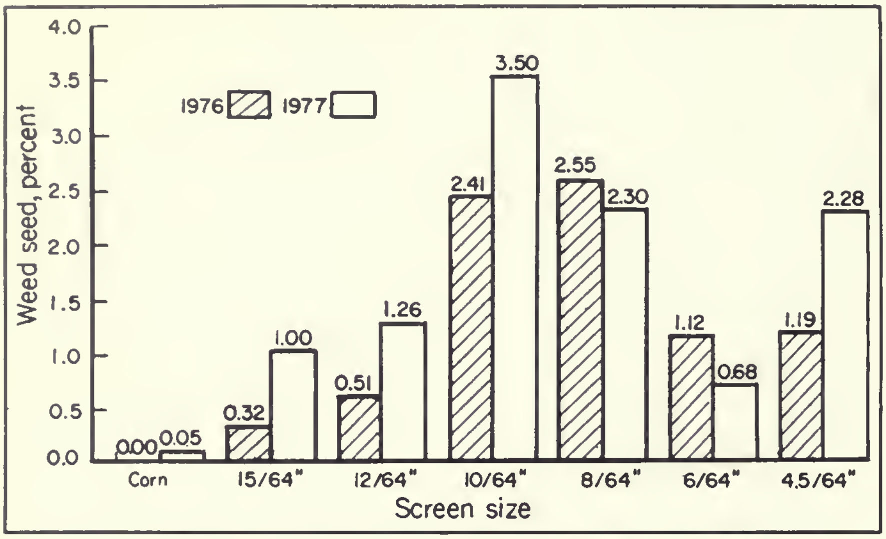

Figure 9. Relationship between particle size and percentage weed seed in corn samples from the 1976 and 1977 crops.*

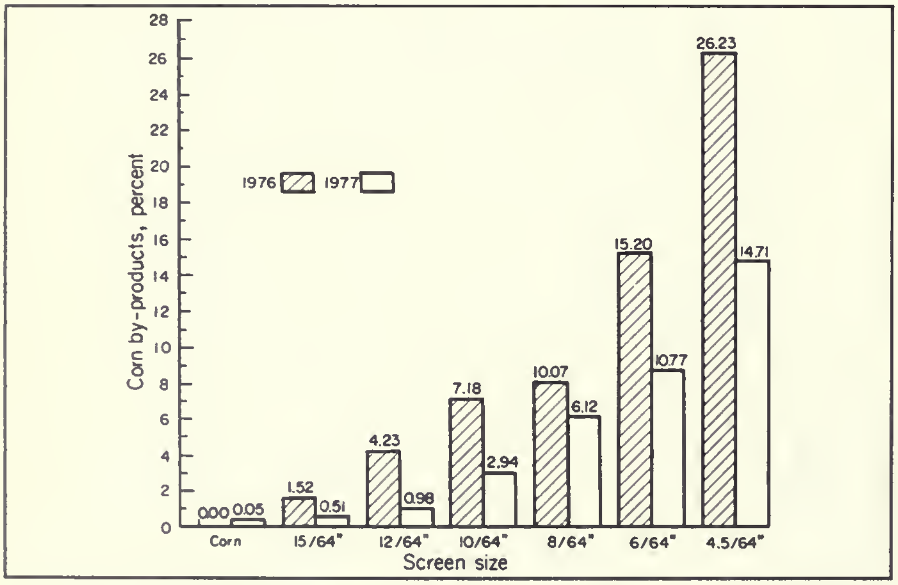

Figure 10. Relationship between particle size and percentage corn by-products in corn samples from the 1976 and 1977 crops.*

* The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen. The category *corn* includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Storage tests

During storage the presence of fines (very fine material) restricts airflow and often makes it difficult to maintain corn quality. It is also known that exposure of the internal starch portion of the kernel and the presence of cracks increase the susceptibility of stored corn to mold.

The effect of particle size (from dust to large pieces of kernels) on mold growth is uncertain. To determine if rate of mold growth varies with particle size, an experiment was conducted on the 1976 corn crop. Material of each particle size from all samples of country elevator receipts was combined in a composite sample. Each composite sample was divided into three identical subsamples, equilibrated to approximately 18 percent moisture, and stored at 80° F. and 80 percent relative humidity in loosely covered flasks in a controlled atmosphere chamber. A similar procedure was used for country elevator shipments, terminal elevator receipts, and terminal elevator shipments. Each week during the 28-week experiment, these samples were exam-

ined and given a numerical rating from 1 to 5 based on the progression of mold growth visible through the glass beaker. The ratings were converted to percentage of material molded to facilitate continuous variable analysis.

No significant differences were found between inbound or outbound samples from terminal elevators and those from country elevators. For that reason, the graph in Figure 11 is based upon data from all samples. The same general pattern of rapid growth during the first two weeks and decreased rate of growth as a maximum level of mold growth was approached is evident for all particle sizes. There are, however, differences between particle sizes in the rate at which mold growth accelerated during the early stages, in the time it took for growth to peak, and in the magnitude of the peak. The three largest particle sizes had the most rapid growth rates and the highest peaks. Mold growth in the 12/64-inch particles was identical to that of the material retained by the 15/64-inch screen. The finest materials apparently lacked sufficient carbohydrates to sustain many of the most rapidly growing molds.

This experiment did not evaluate the detrimental effects of fine material in a bin of corn but only compared the susceptibility to mold growth of the different sizes of particles when held individually under similar conditions. Because the fine material is a serious impediment to airflow in bulk storage, a good environment for insects, and frequently a source of heat and moisture, it is a major contributor to storage losses. These tests show, however, that the small particles provide a less favorable medium for mold growth than larger particles.

A similar conclusion was reached about aflatoxin contamination. All samples were examined under ultraviolet light (365 nanometers) for the bright greenish yellow fluorescence (BGYF) associated with *Aspergillus flavus,* the fungus that produces aflatoxin, and for the presence of aflatoxin. If any fraction of a certain particle size had BGYF, all fractions of every particle size were analyzed for aflatoxin at the Northern Regional Research Center (NRRC), Peoria, Illinois.

The analytical procedure was the CB method approved by the Association of Official Analytical Chemists and the American Association of Cereal Chemists. At the time of collection, any sample above 15 percent moisture was dried at room temperature and stored in a con-

Table 7. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Country Elevator Receipts, Illinois, 1976 Crop

Sample property	Grouping	Particle size groups[a]						
		Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.83						
	B		3.75	4.14	3.84	3.34	3.46	
	C		3.75		3.84	3.34	3.46	2.93
	D							
Ash	A	1.46	1.39	1.62	1.94			
	B	1.46		1.62	1.94	2.36		
	C						3.32	
	D							6.83
Protein	A	10.42	10.27	10.65	10.94			
	B			10.65	10.94	11.22		
	C					11.22	11.70	
	D							12.64
Fiber	A	2.47	2.55	2.98				
	B			2.98	3.38			
	C				3.38	4.05		
	D						5.16	
	E							6.33
NFE	A	80.82	82.03	80.58				
	B	80.82		80.58	79.86	78.97		
	C						76.58	
	D							70.93
Physical								
Corn	A	100.00	97.82					
	B		97.82	93.20				
	C			93.20	89.06			
	D				89.06	83.84		
	E					83.84	78.87	
	F							61.92
Dust and inert mat.	A	0.00	0.00	0.08	0.19	1.27		0.93
	B					1.27	1.98	0.93
Weed seed	A	0.00	0.15	0.83	1.81		3.17	3.10
	B			0.83	1.81	4.20	3.17	3.10
By-products	A	0.00	2.03					
	B		2.03	6.10				
	C			6.10	8.94			
	D				8.94	10.74		
	E						15.92	
	F							34.05

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical charateristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

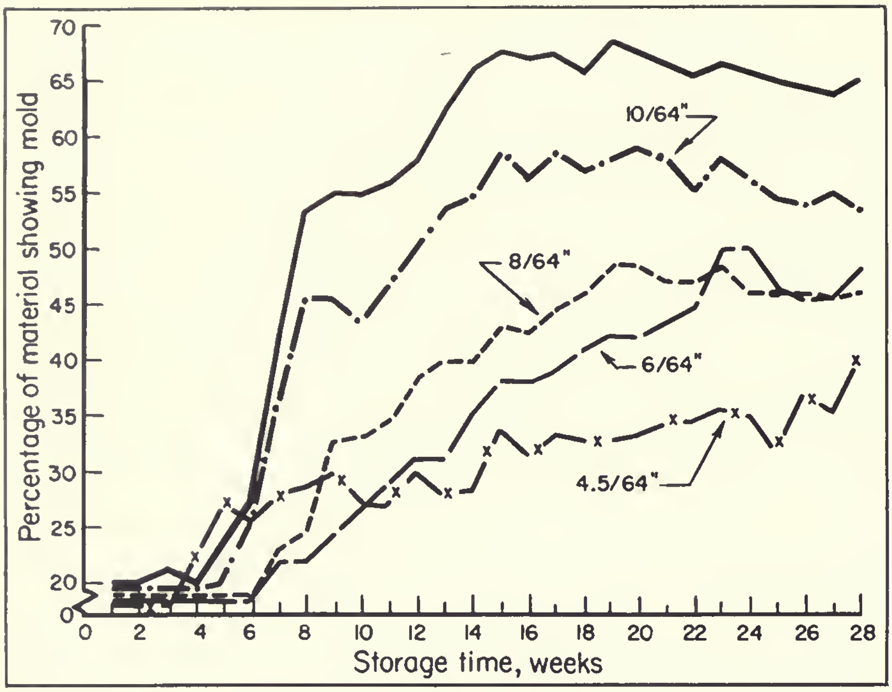

Figure 11. Mold development during storage of selected particle sizes of corn and corn screenings. The number of observations for each screen size ranged from five to two, depending on the quantity of sample available for replication of the experimental observation. The top line is the average for all material above the 10/64-inch screen. Other lines represent materials passing through the respective screen sizes.

trolled atmosphere room at 40° F. The storage time before analysis varied from a few weeks to several months. Information about the samples, such as moisture content at harvest, drying procedures, and storage time, was unknown. Thus, the results do not accurately represent aflatoxin contamination in samples collected from various points in the market channel.

The objective of the tests was to compare contamination among particle sizes, independent of sample history. Because fractions of all particle sizes for each sample were subjected to similar storage conditions, it is valid to compare particle sizes, although differences among them might have become more pronounced as a result of the long period of storage before analysis.

The results of these tests are reported in Table 8. They show that particle size does not significantly affect the level or incidence of aflatoxin. It appears that *A. flavus* is just as likely to invade an apparently sound kernel through a small stress crack or practically invisible weevil hole (followed by aflatoxin formation in the kernel) as it is to grow on the fine screenings in the BCFM.

The percentage of samples showing a positive BGYF test was higher for smaller particles than for whole corn (4 percent for whole corn, compared to 15.9 percent for material passing through a 4.5/64-inch screen). But this trend appeared to be related to the difficulty of detecting the fluorescence in whole kernels or large particles without first grinding the sample. Analyzing all sizes of particles in a sample for aflatoxin, if any particle size showed positive BGYF, revealed that aflatoxin was often present in the whole kernels of a sample, even though fluorescence had not been detected when the whole kernel sample was passed under the ultraviolet light.

The fact that aflatoxin contamination was not associated with particle size is supported by the results of unsuccessful attempts to remove aflatoxin from contaminated corn by physical cleaning to remove fine particles. All these attempts have failed. Removal of grain dust, or fines, will not resolve the aflatoxin problem.

Feeding value

Since corn and corn screenings are used primarily for livestock feed, the effect of changing the screen size upon nutritional value must be evaluated. The chemical analyses shown in Table 7 give an indication of differences in nutritional content among particle sizes but do not reflect the relative value of screenings given the price relationships among various substitutes in livestock rations and the required balance among amino acids.

The primary difference in feeding value between whole corn and corn screenings is that screenings generally have a higher protein content, a higher fiber content, and a lower total energy value. Thus, the relative value of screenings in a ration depends on the relative prices for protein and carbohydrates.

One approach to establishing the value of screenings is to calculate the value of the net energy and the protein in corn and corn screenings, using price relationships for protein and energy from an alternative source. If screenings are defined as material passing through the screen size used to define BCFM, then under present standards all material passing through the 12/64-inch screen would be priced on the basis of its net energy and protein content. By selecting alternative screen sizes to define BCFM, it is possible to compare the value of the screenings defined as all material passing through each screen size selected. The nutrient analysis of screenings obtained from five different sizes of screens is shown in Table 9. It should be

emphasized that the composition of commercial corn screenings may differ from these analyses since the screens used in commercial cleaners often differ in size and type from the USDA standard screen.

To establish the relative value of screenings with different screen sizes, protein was priced on the basis of soybean meal (SBM) at $280 per ton, and digestible energy was priced on the basis of No. 2 corn at $2.66 per bushel, using digestibility coefficients for swine. Corn prices were then converted from the standard 15.5 percent moisture to a dry-matter basis. At the above prices, screenings defined with the 12/64-inch screen would be valued (on a dry-matter basis) at $5.69 per hundredweight when the price of whole corn is $5.62 per hundredweight (Table 10). As the price of SBM is lowered, the value of screenings relative to corn declines. Only when soybean meal prices are very high relative to corn prices

Table 8. Frequency of Aflatoxin Contamination, by Particle Size and Level of Contamination, Illinois, 1976 and 1977 Corn Crops

Level of contamination	Particle size groups[a]						
	Corn[b]	15/64″	12/64″	10/64″	8/64″	6/64″	4.5/64″
Total number of samples tested for BGYF	1,080	1,080	1,080	1,080	1,080	1,080	1,080
Total number of samples showing BGYF +	44	132	103	102	103	83	173
Percentage of total showing BGYF +	4.1	12.2	9.5	9.4	9.5	7.7	16.0
Total number of samples assayed by NRRC	83	113	96	101	104	98	122
Any aflatoxin:							
Number of samples	14.0	10.0	15.0	13.0	11.0	8.0	15.0
Percentage of total	16.9	8.9	16.1	12.9	10.6	8.2	12.3
Over 10 ppb aflatoxin:							
Number of samples	13.0	8.0	11.0	10.0	8.0	6.0	10.0
Percentage of total	15.7	7.1	11.5	9.9	7.7	6.1	8.2
Over 20 ppb aflatoxin:							
Number of samples	7.0	8.0	7.0	7.0	7.0	5.0	9.0
Percentage of total	8.4	7.1	7.3	6.9	6.7	5.1	7.4
Over 50 ppb aflatoxin:							
Number of samples	4.0	4.0	7.0	4.0	5.0	1.0	4.0
Percentage of total	4.8	3.5	7.3	3.96	4.8	1.02	3.3

Note: Includes aflatoxins B_1, B_2, G_1, and G_2. Assays were conducted by the NRRC on all samples showing BGYF in any particle size.
[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.
[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table 9. Specifications for Corn and Corn Screenings

Particle size[a]	Protein, percent of dry matter	Fiber percent of dry matter	Digestible energy, Kcal per lb of dry matter	Lysine, percent of dry matter[b]	Methionine and cystine, percent of dry matter[b]	Tryptophan, percent of dry matter[b]	Palatability limit, percent of total ration
Corn	10.28	2.33	1,785.8	.292	.409	.082	100
Material passing through screen sizes of:							
12/64 in.	11.08	3.73	1,717.3	.315	.441	.088	50
10/64 in.	11.45	4.29	1,691.5	.325	.455	.091	50
8/64 in.	11.86	5.11	1,660.9	.337	.472	.094	25
6/64 in.	12.49	5.76	1,631.8	.355	.497	.099	25
4.5/64 in.	12.27	5.91	1,610.8	.349	.488	.098	25

Note: The figures in this table are averages of 1976 and 1977 values for country elevator receipts.
[a] The screenings under each size category include all material passing through the screen. For example, 12/64 inch includes the material passing through this screen as well as all the smaller screens in the proportion in which these particles were found in the samples collected from country elevator receipts over the two-year period. Corn is the total sample as received by the country elevator.
[b] Amino acid content was based on the proportion of each in the crude protein fraction of whole corn. The composition of the protein was assumed to be constant over all particle sizes. The content of amino acid varies only as the percentage of protein differs among particle sizes.

Table 10. Value of Corn Screenings Based on Prices of Protein and Energy

Market price of: Soybean meal, $/ton	No. 2 corn, $/bu	Derived price of: Protein, ¢/lb	Energy, ¢/1,000 Kcal	Price ratio, protein/energy	Market price of No. 2 corn, $/cwt, dry matter basis	Derived value of corn screenings passing through screen sizes of:[a] 12/64"	10/64"	8/64"	6/64"	4.5/64"
						$/cwt, dry matter basis				
126.16	3.09	0.62	3.62	0.17	6.52	6.28	6.19	6.08	5.98	5.91
205.00	3.23	11.00	3.18	3.50	6.82	6.68	6.64	6.59	6.56	6.47
243.40	3.35	15.74	3.06	5.14	7.08	6.99	6.98	6.95	6.96	6.86
280.00	2.66	24.74	1.72	14.38	5.62	5.69	5.74	5.79	5.90	5.81

[a] Each screen size was used to identify an alternative definition of BCFM and represents all material falling through each of the screens.

does the higher protein content of the screenings make them more valuable than whole corn. In terms of digestible energy and crude protein, the screen size selected for defining BCFM has only a small effect on the value of the screenings in swine rations. The direction and magnitude of the effect depends on the relative price of protein and energy. At recent prices of corn and soybean meal, BCFM defined by any screen size shows a discount relative to corn. This discount increases as screen size decreases.

A more complete comparison of the feeding value of corn of different particle sizes was made, using a linear programming model to determine a least-cost feed ration for swine.[10] With different protein and energy contents in the different categories of screenings, the least-cost ration required different quantities of other feed ingredients to meet the nutritional requirements of the ration. These changes resulted in different rations with different costs per pound of feed and per kilocalorie of energy. Swine nutritionists provided the coefficients for the model and established palatability restrictions on the maximum proportions of screenings that should be included in the ration. Additional research is needed to determine these limits more precisely and the effects of exceeding them, but the values used were thought to approximate current practices in the industry.

The ration specifications and ingredient prices used in the linear programming model are given in Table 11. With the price of soybean meal at $205.20 per ton ($10.26 per hundredweight) and corn and corn screenings priced at $4.75 per hundredweight (15.5 percent moisture), the least-cost ration always contained the maximum quantity of screenings permitted by the palatability restrictions (50 percent for larger particle sizes and 25 percent for smaller particle sizes). The cost per pound of ration was nearly constant, regardless of particle size (Table 12). However, the energy content and the crude protein content differed among the rations. A ration in which corn was the only energy source was compared with a ration in which corn screenings was a possible alternative. The corn screenings ration cost 2 to 3 cents less per 100 pounds of ration, even when corn and screenings were priced at $4.75 per hundredweight. The reason is that corn screenings are higher in protein content. Nevertheless, even though the cost per pound of total ration is lower, the cost per pound of energy is higher for rations containing corn screenings.

Using the digestible energy in each ration and the cost of 100 pounds of the ration, it is possible to calculate the cost per pound of gain for hogs fed rations containing material that has passed through any one of various sizes of screens. Since the ration is balanced on amino acid content and since crude protein contents are quite similar across rations, it was assumed in making these calculations that the rations were all similar in composition except in digestible energy. If it is also assumed that swine between 30 and 100 pounds require 4,342 kilocalories of energy per pound of gain, then the ration containing material passed through the 12/64-inch screen would produce pork at a feed cost of $16.19 per 100 pounds of pork. The ration containing material from a 10/64-inch screen would cost $16.30 per 100 pounds; from the 8/64-inch screen, $16.19; and from the 6/64-inch screen, $16.24. The conclusion based on this simple ration formulation is that changes in screen size for defining BCFM and corn screenings would have only a very small effect on the cost of pork production.

Shadow prices in the linear programming model for corn screenings in swine and beef rations also illustrate the relationship between

Table 11. Prices of Ingredients Used in the Least-Cost Feed Formulation Model for Swine

Ingredient	Price, $/cwt
Corn	4.75
Soybean meal	10.26
Limestone	3.00
Dical	16.00
Salt	5.00
Vitamin-trace mineral premix	21.00
Screenings	4.75
Total ration	5.82

10. The linear programming solutions were run on the Computer Assisted Management Program of Illinois (CAMPI) under the direction of Duane E. Erickson, Department of Agricultural Economics, University of Illinois at Urbana-Champaign.

protein and energy values and the relative value of corn screenings. In rations with higher energy and lower protein requirements, screenings show a relative price discount. In high-protein rations, the screenings have greater value than corn at the prices of corn and soybean meal used in the model.

If BCFM discounts reflect differences in market value, then actual discounts should be closely related to the price of screenings, which should also be related to the value of screenings calculated from prices of corn and soybean meal. The derived price of screenings calculated from the market prices of corn and soybean meal had a correlation coefficient of 0.86 with the monthly price of screenings reported by Illinois country elevators between October, 1975, and September, 1976. Although the market price of screenings is not derived directly from their feeding value, their price apparently reflects prices of alternative feed ingredients. The average annual price of screenings reported at Illinois country elevators between October, 1975, and September, 1976, was $66.75 per ton. This figure is considerably below the average price of $108.25 per ton derived from the value in swine rations. Screenings are priced below their true feed value because of demand and supply factors, transportation costs resulting from locational differences, and differences in quality.

Corn and soybean meal prices on selected dates over a period of several years were used to calculate an implicit discount for BCFM based on protein and energy content. The implicit discount was calculated as the difference between the value of corn with 4 percent BCFM and the value of corn with 3 percent BCFM. The actual discounts reported by Illinois elevators were then compared with these implicit discounts (Table 13). The actual discounts were much larger than the implicit discounts, and they showed little relationship to one another as they changed over time. The actual discounts at most elevators are quite stable from year to year. In a 1981 survey of Illinois elevators, 97.8 percent of the respondents reported no change in their BCFM discounts over a three-year period, despite considerable fluctuation in prices of feed ingredients and corn screenings. Although market prices of corn screenings reflect the value of the screenings, BCFM discounts appear to be unrelated either to prices or feeding value.

Table 12. Least-Cost Rations for Growing Swine Using Corn and Corn Screenings, Balanced on Amino Acid Requirements

	Material passing through a screen size of:					
	Corn[a]	15/64″	12/64″	10/64″	8/64″	6/64″
Pounds of feed in 1,000 lb of ration:						
Corn	802	307	308	556	558	557
Screenings	0	500	500	250	250	250
Soybean meal	164	159	158	160	159	159
Digestible energy, Kcal/lb	1,710	1,675	1,661	1,678	1,671	1,665
Crude protein, percent	16.5	16.7	16.8	16.7	16.8	16.8
Cost of ration, ¢/lb	5.84	5.82	5.81	5.82	5.81	5.82
Cost of ration, ¢/1,000 Kcal	3.415	3.475	3.498	3.468	3.477	3.495

[a] The maximum limit of screenings was set at zero for the corn-only ration. In all other rations, the same quality of corn was available, along with the screenings, at equal prices. The prices for the ingredients are shown in Table 11. D.E. Erickson, Department of Agricultural Economics, University of Illinois at Urbana-Champaign, provided the linear programming results in the table, using the Computer Assisted Management Program of Illinois (CAMPI).

Table 13. Comparison of Actual and Implicit Discounts for BCFM

	Price of soybean meal, $/ton[a]	Corn price, $/bu[b]	Discount, cents per bushel per percentage point of BCFM	
			Actual[c]	Implicit[d]
January, 1974	172.91	2.80	2.14¢	.07¢
August, 1974	152.95	3.495	1.85	.41
October, 1974	169.26	3.695	2.00	.04
January, 1975	126.16	3.090	2.14	.59
October, 1976	171.50	2.39	1.47	.03
April, 1977	274.00	2.40	1.59	.32
October, 1977	136.40	1.74	..[e]	(.03)[f]
April, 1978	172.90	2.47	..[e]	.03
October, 1978	176.30	2.08	..[e]	.01
April, 1979	190.60	2.43	..[e]	.02
October, 1979	182.30	2.55	1.48	.03
February, 1980	174.00	2.52	..[e]	.04
October, 1980	243.40	3.35	1.45	.04
January, 1981	200.50	3.36	..[e]	.08
July, 1981	205.00	3.2275	1.48	.07

[a] Decatur bulk price.
[b] East Central Illinois track price.
[c] Actual discounts were obtained by phone and mail surveys of the grain industry; they were calculated on the basis of 5 percent BCFM, except the 1974 and January, 1975, data, which were calculated on a 10 percent basis.
[d] The implicit discount is the difference in value between corn with 4 percent BCFM and that with 3 percent BCFM, based on the differing levels of protein and energy in the screenings (Table 9).
[e] No data available.
[f] Premium relative to No. 2 corn.

Alternative Screen Sizes for Defining BCFM

Using the information in the preceding section, alternative definitions of BCFM can be evaluated for their effect on chemical and physical composition, on the relative value of the screenings, and on the distribution of samples among the numerical grades.

Differentiation of chemical properties

The present definition of BCFM as material passing through the 12/64-inch screen results in the *least* difference between corn (material above the screen) and screenings (material passing through the screen) on all chemical factors and at all four points sampled in the market channel (Table 14). (The 15/64-inch screen was not included in Table 14 since it allowed small whole kernels to pass through as screenings.) A minor exception to this pattern is found in the terminal elevator shipments, where the difference between corn and screenings on the factor of NFE was smaller for the 10/64-inch than for the 12/64-inch screen. This anomaly was the result of a negative difference in one year cancelling out a positive difference the next year in the 10/64-inch size category.

Since blending and cleaning take place at the country elevators and subterminals, country elevator receipts are the best point at which to make comparisons. As shown in Table 14, the greatest differentiation in ash, protein, fiber, NFE, and kilocalories between corn and screenings is obtained by defining BCFM with a 6/64-inch screen. (The 4.5/64-inch screen was not included in this comparison because so little material passes through this screen that statistical validity of grading would be difficult to achieve.) In the case of fat content, there is little difference between the 8/64- and the 6/64-inch screens, although the 8/64-inch screen gives slightly greater discrimination.

Differentiation of physical properties

The screen size used to separate BCFM from corn has a substantial impact on the physical properties of the screenings removed from a sample. Table 15 shows the effect of four alternative screen sizes on each of four physical properties. The pattern is not as consistent as that of the chemical properties (Table 14), but there is a general increase in the differences between the material above and that below the screen as the size of screen decreases.

For the country elevator samples, the maximum differences in percentage of corn and corn by-products is found with the 6/64-inch screen. There was so little dust and inert material in the samples that the screen size had little effect, although the 6/64- and 8/64-inch screens did a slightly better job of separating dust from corn. The 8/64-inch screen gave the maximum difference in percentage of weed

Table 14. Differences in Chemical Composition Between Corn and BCFM Under Alternative Screen Sizes Used to Define BCFM, 1976-1977 Average

Screen size, inch	Country elevator receipts: Corn[a]	BCFM[b]	Difference	Terminal elevator shipments: Corn[a]	BCFM[b]	Difference
Fat content			*percent of sample weight*			
12/64	4.5	3.3	1.3	4.4	3.4	1.1
10/64	4.5	3.0	1.6	4.4	2.8	1.7
8/64	4.5	2.8	1.7	4.4	2.1	2.3
6/64	4.5	2.8	1.7	4.4	2.0	2.4
Ash content						
12/64	1.4	2.4	0.9	1.4	1.6	0.3
10/64	1.4	2.9	1.5	1.4	1.6	0.3
8/64	1.5	3.7	2.2	1.4	1.8	0.5
6/64	1.4	4.8	3.4	1.4	2.3	0.9
Protein content						
12/64	10.3	11.1	0.8	10.2	10.4	0.2
10/64	10.3	11.5	1.2	10.2	10.5	0.3
8/64	10.3	11.9	1.6	10.2	10.8	0.6
6/64	10.3	12.5	2.2	10.2	11.5	1.3
Fiber content						
12/64	2.3	3.7	1.4	2.1	3.0	0.9
10/64	2.3	4.3	2.0	2.1	3.4	1.3
8/64	2.3	5.1	2.8	2.1	4.2	2.1
6/64	2.3	5.8	3.5	2.1	5.1	3.0
NFE						
12/64	81.4	79.5	1.9	82.0	81.6	0.4
10/64	81.4	78.3	3.1	82.0	81.8	0.2
8/64	81.4	76.6	4.9	82.0	81.2	0.8
6/64	81.5	74.1	7.4	82.0	79.2	2.8
Energy content			*Kilocalories per pound of corn or BCFM*			
12/64	1,785.8	1,717.3	68.4	1,788.8	1,742.9	45.8
10/64	1,785.6	1,691.5	94.1	1,788.6	1,721.8	66.9
8/64	1,785.5	1,660.9	124.6	1,788.4	1,691.9	96.6
6/64	1,785.7	1,631.8	153.9	1,783.1	1,666.9	116.2

Note: These data represent the weighted average of all material passing through each screen size. Values were calculated on a dry weight basis.
[a] Material remaining on top of each screen.
[b] Material passing through each screen.

seeds for the country elevator samples.

The differences among screen sizes at the terminal elevator were similar to those of the country elevator for the properties of corn and corn by-products. At the terminal elevator, most of the inert material and weed seeds have been removed or diluted by the increased amount of broken corn. Even when the 6/64-inch screen is used, 83.2 percent of the material passing through the screen is corn. The percentage of dust and inert material and of weed seeds is so low at the terminal elevator that the size of the screen makes little difference in its ability to separate corn from noncorn with the alternative definitions of BCFM.

At each smaller screen size, the chemical and physical properties of corn are being compared to a smaller quantity of BCFM. The maximum difference is found with the smallest screen size. However, less than 0.2 percent of the average sample at the country elevator would pass through the 6/64-inch screen (Table 6). The increase in differences with decreasing screen size shows that the smaller screens improve the differentiation between corn and noncorn and thereby come closer to the objective of separating foreign material from broken corn in the grading system.

Distribution among grades

The percentage of sample that falls in each numerical grade depends not only on the screen size, but on the maximum limits permitted for BCFM under each screen size definition. Under present standards the BCFM limits for No. 1, No. 2, No. 3, No. 4, and No. 5 grades are 2, 3, 4, 5, and 7 percent, respectively. The percentage of corn samples grading No. 1 (using the 12/64-inch screen) declined as the corn moved through the market channel from 81.4 percent of the farm deliveries to 64.7 percent of the country elevator shipments to 40.1 percent of terminal elevator shipments (Table 16). The change that occurred as the corn moved through the market system resulted from increased breakage and from the cleaning and blending done by the elevators in response to the lack of economic incentives for selling No. 1 corn.

On the factor of BCFM, 93.1 percent of the country elevator receipts were No. 2 or better; that is, there were no discounts for BCFM. There is no objective criterion by which one can establish that this distribution is the "right" one. Conversely, there is no basis for saying that more samples or fewer samples should be discounted. In the absence of a rationale for changing the distribution among grades, it was decided to search for the grade limits for each screen size that would approximate the 1976-1977 actual distribution.

If BCFM were defined as material passing through a 10/64-inch screen, the limits for No. 1 through 5 numerical grades would have to be 1.2, 1.8, 2.4, 3.0, and 4.0 percent, respectively, to attain a distribution similar to that found with current standards (Table 16). Selection of limits for a 10/64-inch screen to approximate the present distribution of numerical grades for country elevator receipts also maintained the 1976-1977 distribution of samples among grades for other points in the market channel. The biggest shift occurred with terminal elevator shipments, where there was a higher proportion of samples in the No. 4 and No. 5 grades than under present standards. Increased breakage of corn into smaller and smaller pieces as it moved through the market channel was evident.

It must be recognized that grain firms have been screening and blending to the 12/64-inch standard. If grain firms were given an opportunity to blend to a new standard and discounts were established on the basis of a new screen size, it is quite probable that the quantity of each particle size would change and that the distribution among grades would be altered at the terminal elevator. Changes in screen size would have much less

Table 15. Difference in Physical Properties Between Corn and BCFM Under Alternative Screen Sizes Used to Define BCFM, 1976-1977 Average

Screen size, inch	Country elevator receipts			Terminal elevator receipts		
	Corn[a]	BCFM[b]	Difference	Corn[a]	BCFM[b]	Difference
Corn			*percent of sample weight*			
12/64..........	99.9	87.8	12.1	99.9	92.7	7.2
10/64..........	99.9	83.1	16.8	99.9	90.0	9.9
8/64...........	99.9	77.7	22.2	99.9	86.5	13.4
6/64...........	99.8	71.9	27.9	98.8	83.2	15.6
Dust and inert material						
12/64..........	0.0	0.4	0.4	0.0	0.1	0.1
10/64..........	0.0	0.6	0.6	0.0	0.2	0.2
8/64...........	0.0	1.0	1.0	0.0	0.3	0.3
6/64...........	0.0	1.0	1.0	0.0	0.3	0.3
Weeds						
12/64..........	0.02	2.9	2.9	0.03	0.7	0.7
10/64..........	0.03	3.9	3.9	0.04	0.8	0.8
8/64...........	0.04	4.2	4.2	0.04	0.7	0.7
6/64...........	0.05	3.8	3.8	0.05	0.4	0.4
Corn by-products						
12/64..........	0.05	9.0	9.0	0.03	6.6	6.6
10/64..........	0.07	12.4	12.3	0.05	9.1	9.1
8/64...........	0.10	17.2	17.1	0.08	12.6	12.5
6/64...........	0.11	23.4	23.3	0.12	16.3	16.2

Note: These data represent the weighted average of all material passing through each screen size. Values were calculated on a dry weight basis.
[a] Material remaining on top of each screen.
[b] Material passing through each screen.

effect on the particle size distribution of country elevator receipts since farmers have less need and fewer opportunities to blend. The percentage of farm production falling in each grade would remain approximately as shown in Table 16.

Smaller screen sizes require much lower limits to maintain a similar distribution. In fact, with the 6/64-inch screen, the No. 1 limit is probably too low to be measured with any statistical reliability.

If the 10/64-inch, the 8/64-inch, or the 6/64-inch screens were used to determine BCFM, only a small amount of material would have to be removed to meet No. 2 standards at any point in the market. According to 1976 and 1977 data on country elevator receipts, less than 0.8 percent of the total sample weight was passed through the 10/64-inch screen, less than 0.4 percent through the 8/64-inch screen, and less than 0.3 percent through the 6/64-inch screen (Table 6). Even in the terminal elevator shipments, just under 1 percent of the material passed through the 8/64-inch screen and under 0.6 percent through the 6/64-inch screen.

Meeting the No. 2 limits of Table 16 for the 8/64-inch screen would not require removal of any screenings from the average lot of corn from the terminal elevator or the country elevator, although many individual samples would exceed the limit. More specifically, with the 8/64-inch screen and the limits listed in Table 16, 91.4 percent of the country elevator receipts would require no cleaning to meet the No. 2 standard; 84.8 percent of the country elevator shipments, 82.8 percent of the terminal receipts, and 67.4 percent of the terminal shipments would meet the standard without cleaning. One result of changing the screen size would be a reduction in cleaning requirements and a major reduction in the volume of corn screenings on the market for use in feed.

Changing the screen size would have a very small effect on the physical and chemical properties of corn because the quantity of such materials as broken corn and weed seeds is small compared to the weight of the rest of the sample. For example, changing from a 12/64-inch screen to a 10/64-inch screen would add 0.52 percent of the average sample delivered by Illinois farmers that is now BCFM to the 98.63 percent of the sample that is now considered corn (Table 6). Since the chemical and physical properties of the 10/64-inch material differ very little from those of corn, the chemical and physical analysis of the corn fraction of the samples would not be appreciably altered.

Table 16. Distribution of Corn Samples Among Various Grades Based on the Maximum BCFM Limits for Alternative Screen Sizes, Illinois, 1976 and 1977 Crops

Screen size and grade[a]	Maximum BCFM content, percent[b]	Country elevators Receipts	Country elevators Shipments	Terminal elevators Receipts	Terminal elevators Shipments
		percent			
12/64 inch					
U.S. No. 1....	2.0	81.4	64.7	67.6	40.1
U.S. No. 2....	3.0	11.7	19.7	17.8	33.5
U.S. No. 3....	4.0	4.8	9.7	6.8	17.3
U.S. No. 4....	5.0	1.1	4.2	4.0	5.4
U.S. No. 5....	7.0	0.3	1.4	2.8	1.2
Sample	>7.0	0.7	0.3	2.0	2.5
10/64 inch					
U.S. No. 1....	1.2	81.7	68.2	66.0	41.3
U.S. No. 2....	1.8	9.7	16.2	18.0	27.7
U.S. No. 3....	2.4	5.8	8.0	5.6	14.3
U.S. No. 4....	3.0	1.1	4.1	3.8	8.3
U.S. No. 5....	4.0	0.7	2.8	4.0	4.9
Sample	>4.0	1.0	0.7	3.6	2.5
8/64 inch					
U.S. No. 1....	0.6	83.4	68.9	65.2	38.8
U.S. No. 2....	1.0	8.0	15.9	17.6	28.6
U.S. No. 3....	1.4	4.8	6.9	6.4	14.0
U.S. No. 4....	1.8	1.4	3.1	3.2	9.5
U.S. No. 5....	2.6	1.7	4.2	4.0	5.8
Sample	>2.6	0.7	1.0	3.6	3.3
6/64 inch					
U.S. No. 1....	0.3	84.5	69.2	64.4	46.3
U.S. No. 2....	0.6	7.6	18.0	19.6	25.2
U.S. No. 3....	0.9	4.8	5.2	7.6	15.3
U.S. No. 4....	1.2	0.0	3.5	2.4	6.2
U.S. No. 5....	1.8	2.1	2.4	2.8	4.5
Sample	>1.8	1.0	1.4	3.2	2.5

[a] Each screen size was used to identify an alternative definition of BCFM and represents all material falling through that screen.
[b] BCFM limits for the 12/64-inch screen are those currently used in corn grading. BCFM limits for other screen sizes were selected so that the samples from a given location would be distributed approximately the same, regardless of the screen size used.

Summary and Conclusions

Many economic and engineering relationships and trade practices are involved in any change of grade standards for grain. Because of the complexity of market relationships and the difficulty in predicting the

response of the market to a change in standards, it is impossible to provide quantitative proof that changing the definition of BCFM would result in greater benefits than costs. For the same reasons, it is equally impossible to prove that the benefits of the present standards exceed their costs.

The research reported in this publication provides information that should help the grain industry and Federal Grain Inspection Service, USDA, evaluate the potential improvement in market information that might result from changing the screen size used to define foreign material in corn. Unfortunately, the results do not provide the basis for a clear, unequivocal mandate. The following conclusions should help the reader better understand the implications of this research by bringing its results to bear upon the operational problems of grain production and marketing industries.

- Whole corn, broken corn, and noncorn materials cannot readily be separated by sizing devices such as screens because particles of all three kinds of material vary widely in size and because the size groups overlap. Although hand-separation of large noncorn material from the sample will increase inspection costs, it is being done in other major corn-exporting countries. It may be possible to make coarse foreign material a separate factor in conjunction with a change in screen size.
- The maximum number of chemical and physical differences between corn and foreign material was obtained using an 8/64- or 6/64-inch screen. The two screens do not differentiate with equal success for all chemical and physical properties, but either screen would separate most dirt and weed seeds from corn.
- No criteria have been established for determining the "best" distribution of the corn crop among the five numerical grades. It would be less difficult to establish price relationships and discounts if the present distribution were maintained. Using smaller screen sizes would require a reduction in the foreign material allowances for each grade.
- Using one of the smaller screens would minimize the amount of material that must be removed to meet the standard for No. 2 corn at all points in the marketing channel. As a result, the smaller screen would sharply reduce the amount of cleaning needed and the volume of screenings marketed. If screenings were treated as dockage (zero value), one may conjecture that the sharply reduced allowances and amounts of screening material would lessen the incentive for farmers to intentionally permit some foreign matter to get mixed with the corn. Treating screenings as dockage should also remove the incentive for blending screenings back into corn. Much of the foreign matter would be concentrated in a relatively small quantity of screenings, for which errors in pricing would not be a major concern.
- If broken corn is considered lower in value than whole corn (and there is evidence supporting this belief), an additional grade factor, *whole kernels*, might be required in conjunction with the definition of foreign material by a smaller screen. This factor could be similar to the categories, *splits* versus *whole beans*, in the soybean grades. Using a smaller screen size for defining FM and creating a broken kernel factor would have several advantages. The chemical properties of No. 2 corn purchased by the feed industry would be very similar to those of corn now purchased. The industry would have little or no reason to discount against broken kernels. Processors could encourage the market to direct corn with less breakage to the processing industry by appropriate discounts for broken kernels. If there were appropriate market discounts against foreign material, most of the corn dust would be removed at its origin, and grain handlers would have no incentive for reblending dust or material smaller than 6/64-inch. With these small pieces removed, much of the broken corn that became dust as a result of increased handling would also be removed. The value of foreign material (or dust) going through the small screen would be much less than at present. The screenings market, as it now exists, would probably disappear.
- Using a smaller screen size would result in several changes in the characteristics of corn and foreign material. The value of screenings could be reduced since they would then be higher in fiber and lower in digestible energy but higher in protein than screenings passing through a 12/64-inch screen. They would also contain more weed seeds and would be more difficult to dry and store because of restricted airflow. Although no change in the chemical properties of the corn would be detectable, there would be more broken pieces of corn in the corn fraction, and these pieces would be smaller than under the present standards. For corn processors the presence of more broken pieces would generally be a disadvantage. Although the majority of U.S. corn is used for livestock feed (domestically and overseas), processors needs and influence on market prices cannot be ignored.
- There is no alternative (including the status quo) that does not have some disadvantage to some groups. The choice of an alternative should be reached through compromise and minimization of negative effects. Additional research is needed that includes the export elevators. Information is also needed about the effect of particle size on processing costs, handling procedures, and grading costs, and about the effect of redefining the grade factors on prices. Differences between crop years and over a larger region should also be evaluated. This study provides much of the basic information on which a more comprehensive research project can be built.

Appendix A: Statistical Differences in Chemical and Physical Properties

Table A1. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, All Samples, Illinois, 1976 Crop

Sample property	Grouping	Particle size groups[a] Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.66		4.51				
	B		4.04		3.89			
	C					2.90	2.73	2.64
Ash	A	1.39	1.39	1.63	1.66	1.67		
	B			1.63	1.66	1.67	2.32	
	C							4.94
Protein	A	10.18	10.01	10.28	10.37			
	B	10.18		10.28	10.37	10.45		
	C						10.93	
	D							12.12
Fiber	A	2.31	2.41					
	B			2.74	3.01			
	C					3.50		
	D						4.24	
	E							5.92
NFE	A	81.47	82.10		81.06	81.54		
	B	81.47		80.83	81.06	81.54		
	C			80.83	81.06		79.99	
	D							74.26
Physical								
Corn	A	100	98.13					
	B			95.26				
	C				90.35			
	D					86.79		
	E						82.74	
	F							72.22
Dust and	A	0	0.03	0.05	0.06			0.37
inert mat.	B					0.60	0.93	
	C					0.60		0.37
Weed seed	A	0	0.32	0.51			1.12	1.19
	B				2.41	2.55	1.12	1.19
By-products	A	0	1.52					
	B			4.23				
	C				7.18			
	D					10.07		
	E						15.20	
	F							26.23

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A2. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, All Samples, Illinois, 1977 Crop

Sample property	Grouping	Particle size groups[a] Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.29						
	B		3.71					
	C			4.01				
	D				2.91			
	E					2.05	2.12	2.21
Ash	A	1.39	1.38	1.64	1.59	1.78		
	B						2.39	
	C							4.24
Protein	A	10.21	10.12	10.42	10.39	10.43		
	B						11.00	
	C							12.42
Fiber	A	2.07	2.27					
	B		2.27	2.54				
	C			2.54	2.77			
	D					3.52		
	E						4.23	
	F							5.90
NFE	A	82.05	82.52		82.35	82.22		
	B	82.05		81.39		82.22		
	C						80.26	
	D							75.23
Physical[c]								
Corn	A	99.90	98.49	97.75				
	B				93.61	91.42		
	C						87.75	
	D							83.01
Dust and inert mat.	A	0.00	0.00	0.00	0.02	0.16		0.22
	B						0.82	
Weed seed	A	0.05	1.00	1.26			0.68	
	B		1.00	1.26		2.30	0.68	2.28
	C				3.50	2.30		2.28
By-products	A	0.05	0.51	0.98				
	B				2.94			
	C					6.12		
	D						10.77	
	E							14.71

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A3. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Country Elevator Receipts, Illinois, 1977 Crop

Sample property	Grouping	Particle size groups[a]						
		Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.21						
	B		3.33	3.41				
	C				2.65		2.36	2.44
	D					2.17	2.36	2.44
Ash	A	1.40	1.36	1.66	1.94			
	B			1.66	1.94	2.43		
	C					2.43	3.32	
	D							5.98
Protein	A	10.13	9.92	10.53	10.96	11.09		
	B	10.13		10.53	10.96	11.09	11.43	
	C							13.70
Fiber	A	2.14	2.47	2.93				
	B			2.93	3.41			
	C					4.35	4.68	
	D							6.44
NFE	A	82.11	82.92	81.45	81.04			
	B	82.11		81.45	81.04	79.96		
	C					79.96	78.22	
	D							71.45
Physical								
Corn	A	99.88	99.03	96.53				
	B			96.53	90.00			
	C				90.00	88.89	86.12	
	D							74.15
Dust and	A	0.00	0.00	0.00	0.09	0.20		0.00
inert mat.	B						1.17	
Weed seed	A	0.05	0.45	2.61	7.21	5.48	1.94	6.93
By-products	A	0.07	0.52	0.86	2.70			
	B				2.70	5.42		
	C						10.83	
	D							18.92

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A4. **Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Country Elevator Shipments, Illinois, 1976 Crop**

Sample property	Grouping	Particle size groups[a]						
		Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.40	4.16	4.56				
	B		4.16		3.70			
	C					2.85	2.72	2.99
Ash	A	1.39	1.47	1.63	1.64	1.50	2.68	
	B							6.36
Protein	A	10.16	10.07	10.23	10.32	10.34	10.94	
	B							12.28
Fiber	A	2.29	2.54	2.76				
	B			2.76	3.06			
	C				3.06	3.40		
	D						4.35	
	E							6.00
NFE	A	81.76	81.62	80.82	81.27	81.90	79.41	
	B							72.33
Physical								
Corn	A	100	97.91					
	B		97.91	95.28				
	C				89.33	87.57		
	D						82.83	
	E							74.33
Dust and inert mat.	A	0.00	0.00	0.10	0.00	0.79		0.27
	B					0.79	1.17	
Weed seed	A	0.00	0.66	0.48				
	B		0.66	0.48		1.60	0.63	0.29
	C				2.80	1.60		
By-products	A	0.00	1.42	4.14				
	B			4.14	7.88			
	C				7.88	10.04		
	D						15.37	
	E							25.11

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A5. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Country Elevator Shipments, Illinois, 1977 Crop

Sample property	Grouping	Particle size groups[a]						
		Corn[b]	15/64″	12/64″	10/64″	8/64″	6/64″	4.5/64″
Chemical								
Fat	A	4.20		4.42				
	B	4.20	3.98					
	C				3.03			
	D					2.01	2.09	2.17
Ash	A	1.38	1.43	1.70	1.56	1.77		
	B			1.70	1.56	1.77	2.30	
	C							3.64
Protein	A	10.10	10.15	10.39	10.20	10.12	10.78	
	B							12.05
Fiber	A	2.16	2.31	2.60	2.73			
	B				2.73	3.26		
	C						4.05	
	D							5.73
NFE	A	82.16	82.13	80.90			80.78	
	B	82.16	82.13		82.48	82.84		
	C							76.42
Physical								
Corn	A	99.88	97.24	97.68				
	B				90.93	92.43	89.45	
	C				90.93		89.45	88.35
Dust and inert mat.	A	0.00	0.00	0.00	0.00	0.00	0.37	0.90
Weed seed	A	0.05	2.28	1.43		1.86	0.25	0.38
	B				5.71			
By-products	A	0.07	0.49	0.89				
	B				3.36			
	C					5.72		
	D						9.92	
	E							11.27

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A6. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Terminal Elevator Receipts, Illinois, 1976 Crop

Sample property	Grouping	Particle size groups[a] Corn	15/64″	12/64″	10/64″	8/64″	6/64″	4.5/64″
Chemical								
Fat	A	4.91		4.86				
	B		4.06		4.13			
	C					2.82	2.61	2.50
Ash	A	1.35	1.30	1.66	1.56	1.47	1.79	
	B							4.10
Protein	A	10.04	9.74	10.16	9.98	10.16		
	B	10.04		10.16	9.98	10.16	10.49	
	C							11.37
Fiber	A	2.27	2.22	2.65				
	B			2.65	2.81			
	C				2.81	3.25		
	D					3.25	3.70	
	E							5.66
NFE	A	81.43	82.68	80.68	81.52	82.30	81.46	
	B							76.25
Physical								
Corn	A	100	98.41	96.32				
	B				90.38	86.89		
	C					86.89	84.14	
	D							75.17
Dust and inert mat.	A	0.00		0.00	0.00	0.00	0.00	0.00
	B		0.15					
Weed seed	A	0.00	0.05	0.44	3.93	3.13	0.00	0.75
By-products	A	0.00	1.39	3.24				
	B		1.39	3.24	5.69			
	C				5.69	9.98		
	D						15.86	
	E							24.09

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A7. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Terminal Elevator Receipts, Illinois, 1977 Crop

Sample property	Grouping	Particle size groups[a]						
		Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.33		3.98				
	B		3.79	3.98				
	C				2.86			
	D					2.06	2.10	2.22
Ash	A	1.37	1.38	1.58	1.49	1.48	1.86	
	B							4.48
Protein	A	10.24	10.17	10.39	10.27	10.37		
	B						10.88	
	C							11.88
Fiber	A	1.91	2.24	2.37				
	B		2.24	2.37	2.62			
	C					3.34		
	D						3.94	
	E							5.56
NFE	A	82.15	82.41	81.70	82.76	82.75	81.22	
	B							75.86
Physical								
Corn	A	99.92	99.11	98.09				
	B		99.11	98.09	96.78			
	C					92.33		
	D						88.15	86.79
Dust and	A	0.00	0.00	0.00	0.00	0.00		0.00
inert mat.	B						0.24	
Weed seed	A	0.05	0.23	0.41	0.53		0.23	
	B		0.23	0.41	0.53	0.98	0.23	1.06
By-products	A	0.03	0.66	1.49				
	B		0.66	1.49	2.69			
	C					6.69		
	D						11.37	12.16

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A8. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Terminal Elevator Shipments, Illinois, 1976 Crop

Sample property	Grouping	Particle size groups[a] Corn[b]	15/64"	12/64"	10/64"	8/64"	6/64"	4.5/64"
Chemical								
Fat	A	4.52	4.24	4.56				
	B		4.24		3.93			
	C					2.54	2.18	2.08
Ash	A	1.34	1.38	1.63	1.43			
	B	1.34	1.38		1.43	1.25	1.32	
	C							2.45
Protein	A	10.02	9.89	10.02	10.11	9.90		
	B				10.11		10.40	
	C							12.01
Fiber	A	2.15	2.26	2.50				
	B		2.26	2.50	2.66			
	C					3.26		
	D						3.74	
	E							5.67
NFE	A	81.96	82.22	81.29	81.87			
	B	81.96	82.22		81.87		82.45	
	C		82.22			83.05	82.45	
	D							77.93
Physical								
Corn	A	100	98.54	96.77				
	B				93.25			
	C					89.45	86.12	
	D							79.63
Dust and inert mat.	A	0.00	0.00	0.01	0.05	0.09	0.20	0.14
Weed seed	A	0.00	0.36	0.24	1.16	1.11	0.28	0.34
By-products	A	0.00	1.11	2.99				
	B			2.99	5.54			
	C					9.36		
	D						13.40	
	E							19.90

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Table A9. Duncan's Multiple Range Test for Significant Differences in the Chemical and Physical Properties of Corn Samples, by Particle Size, Terminal Elevator Shipments, Illinois, 1977 Crop

Sample property	Grouping	Particle size groups[a]						
		Corn[b]	15/64″	12/64″	10/64″	8/64″	6/64″	4.5/64″
Chemical								
Fat	A	4.41		4.25				
	B		3.72					
	C				3.08			
	D					1.96	1.94	2.03
Ash	A	1.40	1.35	1.62	1.38	1.43		
	B	1.40		1.62	1.38	1.43	2.09	
	C							2.85
Protein	A	10.37	10.23	10.39	10.12	10.13		
	B						10.90	
	C							12.05
Fiber	A	2.07	2.07	2.25	2.32			
	B					3.14		
	C						4.24	
	D							5.89
NFE	A	81.77	82.63	81.50			80.83	
	B	81.77		81.50				
	C		82.63		83.10	83.35		
	D							77.18
Physical								
Corn	A	99.92	98.60	98.71	96.74			
	B					92.03		
	C						87.26	
	D							82.75
Dust and inert mat.	A	0.00	0.00	0.00	0.00	0.43	1.51	0.00
Weed seed	A	0.05		0.61	0.54	0.88	0.29	0.74
	B		1.03	0.61	0.54	0.88	0.29	0.74
By-products	A	0.03	0.37	0.68	3.01			
	B					6.66		
	C						10.94	
	D							16.51

Note: Means within the same grouping are not significantly different at the 95 percent confidence level. Each physical and chemical characteristic was evaluated independently of other characteristics.

[a] The size of particles in each category lies between that screen size and the next smaller one. For example, the material in the 10/64-inch category passed through the 10/64-inch screen but was too large to pass through the 8/64-inch screen.

[b] Includes whole corn and large pieces of broken corn remaining on top of the 15/64-inch screen.

Appendix B: Distribution of Corn Samples, by BCFM Content

Table B1. Distribution of Corn Samples, by BCFM Content Based on Segregation Using a 12/64-inch Screen, Illinois, 1976 and 1977 Crops

BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
1976				
0.0-1.0	58	31	31	11
1.1-2.0	21	36	38	23
2.1-3.0	13	18	17	31
3.1-4.0	6	7	6	21
4.1-5.0	1	5	3	8
5.1-6.0	..	2	1	2
6.1-7.0	..	..	2	..
Over 7.0	1	1	2	4
Avg. BCFM content	1.30	1.81	1.90	2.79
1977				
0.0-1.0	62	27	24	2
1.1-2.0	24	34	41	47
2.1-3.0	8	23	16	38
3.1-4.0	3	14	8	11
4.1-5.0	2	2	6	2
5.1-6.0	..	..	3	..
6.1-7.0	1	..	..	..
Over 7.0	..	..	2	..
Avg. BCFM content	1.11	1.88	2.13	2.20

Table B2. Distribution of Corn Samples, by BCFM Content Based on Segregation Using a 10/64-Inch Screen, Illinois, 1976 and 1977 Crops

BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
1976				
0.0-0.5	58	33	33	12
0.6-1.0	16	29	30	15
1.1-1.5	9	17	16	21
1.6-2.0	11	8	9	19
2.1-2.5	3	3	3	16
2.6-3.0	1	5	1	6
3.1-3.5	1	2	3	4
Over 3.5	1	3	5	7
Avg. BCFM content	0.76	1.04	1.16	1.80
1977				
0.0-0.5	60	27	18	3
0.6-1.0	25	24	34	31
1.1-1.5	5	23	23	33
1.6-2.0	3	11	6	16
2.1-2.5	4	10	8	9
2.6-3.0	1	3	4	15
3.1-3.5	..	1	2	1
Over 3.5	2	..	5	1
Avg. BCFM content	0.64	1.13	1.39	1.42

Table B3. Distribution of Corn Samples, by BCFM Content Based on Segregation Using an 8/64-Inch Screen, Illinois, 1976 and 1977 Crops

BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
1976				
0.0-0.3	65	49	48	16
0.4-0.6	17	23	23	22
0.7-0.9	7	11	12	18
1.0-1.2	6	5	6	15
1.3-1.5	2	4	2	15
1.6-1.8	1	2	1	1
1.9-2.1	1	2	2	3
Over 2.1	1	5	6	10
Avg. BCFM content	0.42	0.57	0.65	1.03
1977				
0.0-0.3	70	37	30	12
0.4-0.6	18	28	26	34
0.7-0.9	4	14	21	24
1.0-1.2	3	12	5	13
1.3-1.5	1	5	9	6
1.6-1.8	2	2	2	8
1.9-2.1	..	1	..	1
Over 2.1	2	1	7	2
Avg. BCFM content	0.33	0.60	0.82	0.81

Table B4. Distribution of Corn Samples, by BCFM Content Based on Segregation Using a 6/64-Inch Screen, Illinois, 1976 and 1977 Crop

BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
1976				
0.0-0.2	76	66	61	30
0.3-0.4	10	15	20	26
0.5-0.6	5	7	7	11
0.7-0.8	6	3	3	16
0.9-1.0	..	2	2	4
1.1-1.2	..	2	1	4
1.3-1.4	1	1	1	2
Over 1.4	2	4	5	7
Avg. BCFM content	0.24	0.31	0.36	0.55
1977				
0.0-0.2	83	49	41	29
0.3-0.4	6	23	23	38
0.5-0.6	5	15	14	12
0.7-0.8	2	8	12	5
0.9-1.0	1	1	3	10
1.1-1.2	..	3	2	4
1.3-1.4	2	..	1	1
Over 1.4	1	1	4	1
Avg. BCFM content	0.18	0.33	0.47	0.46

Appendix C: Cumulative Frequency Distribution of Corn Samples, by BCFM Content

Table C1. Cumulative Frequency Distribution of Corn Samples, by Maximum BCFM Content and Origin of the Sample, Illinois, 1976 and 1977 Crops, 12/64-Inch Screen

Max. BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
0.2	13.1	1.7	0.8	0.0
0.4	27.9	5.9	3.2	0.0
0.6	39.3	14.2	13.2	1.2
0.8	48.6	23.2	22.4	2.1
1.0	59.7	29.8	27.6	7.0
1.2	66.9	35.6	36.4	9.9
1.4	69.6	44.6	44.4	16.1
1.6	74.8	50.9	53.2	24.8
1.8	78.3	58.1	58.8	34.7
2.0	81.4	64.7	67.6	40.1
2.2	83.4	70.6	72.4	49.2
2.4	86.9	76.1	76.4	55.4
2.6	88.6	78.9	80.4	59.9
2.8	90.7	81.7	82.4	66.5
3.0	93.1	84.4	84.4	73.6
3.2	94.8	86.5	87.2	77:3
3.4	95.9	88.2	88.4	81.0
3.6	96.5	90.3	89.6	85.1
3.8	97.2	92.7	90.4	89.3
4.0	97.9	94.1	91.2	90.9
4.2	98.3	94.8	92.4	92.6
4.4	98.6	96.2	92.3	93.8
4.6	98.6	96.9	93.6	94.6
4.8	99.0	97.2	95.2	95.5
5.0	99.0	98.3	95.2	96.3
5.2	99.0	98.3	95.6	96.7
5.4	99.0	99.0	95.6	97.1
5.6	99.0	99.0	96.8	97.1
5.8	99.0	99.3	96.8	97.1
6.0	99.0	99.3	97.2	97.5
6.2	99.0	99.3	97.6	97.5
6.4	99.0	99.7	98.0	97.5
6.6	99.0	99.7	98.0	97.5
6.8	99.0	99.7	98.0	97.5
7.0	99.3	99.7	98.0	97.5

Table C2. **Cumulative Frequency Distribution of Corn Samples, by Maximum BCFM Content and Origin of the Sample, Illinois, 1976 and 1977 Crops, 10/64-Inch Screen**

Max. BCFM content, percent of weight	Counry elevators		Terminal elevators	
	Receipts	Shipments	Rceipts	Shipments
	percent of samples			
0.1	23.1	4.8	2.0	0.0
0.2	36.6	13.1	7.6	0.8
0.3	42.1	19.7	15.2	2.1
0.4	54.8	26.0	21.6	4.1
0.5	59.0	31.1	27.2	8.3
0.6	63.4	38.1	35.6	10.7
0.7	69.0	43.3	40.8	13.6
0.8	72.4	48.8	45.2	19.0
0.9	75.5	53.6	52.8	23.6
1.0	78.3	57.8	58.0	30.2
1.1	80.7	64.4	62.4	36.8
1.2	81.7	68.2	66.0	41.3
1.3	82.4	72.3	70.8	45.9
1.4	85.2	75.4	72.4	51.2
1.5	86.2	77.9	77.6	55.8
1.6	88.6	80.3	80.4	59.9
1.7	89.0	82.4	81.2	64.5
1.8	91.4	84.4	84.0	69.0
1.9	92.8	86.2	84.4	71.1
2.0	94.1	87.2	85.2	73.6
2.1	95.2	88.6	86.4	75.2
2.2	95.9	88.9	88.0	79.3
2.3	96.6	91.0	89.2	81.8
2.4	97.2	92.4	89.6	84.3
2.5	97.6	92.4	90.4	86.8
2.6	97.9	93.4	90.4	88.4
2.7	97.9	94.5	91.6	89.7
2.8	97.9	95.1	91.6	91.3
2.9	98.3	95.8	92.0	92.6
3.0	98.3	96.5	92.4	92.6
3.1	98.3	96.5	93.2	93.4
3.2	98.6	96.5	94.0	93.4
3.3	98.6	96.9	94.4	94.2
3.4	98.6	96.9	94.4	94.2
3.5	98.6	98.3	95.2	95.5
3.6	99.0	98.3	95.2	95.5
3.7	99.0	98.6	95.2	95.9
3.8	99.0	99.0	95.2	96.3
3.9	99.0	99.0	96.0	96.7
4.0	99.0	99.3	96.4	97.5

Table C3. **Cumulative Frequency Distribution of Corn Samples, by Maximum BCFM Content and Origin of the Sample, Illinois, 1976 and 1977 Crops, 8/64-Inch Screen**

Max. BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
0.1	42.4	21.8	15.6	4.5
0.2	60.3	35.3	29.2	9.9
0.3	66.6	45.0	40.8	14.5
0.4	74.5	55.7	49.6	21.1
0.5	78.6	62.3	58.4	29.8
0.6	83.4	68.9	65.2	38.8
0.7	84.8	73.4	69.2	47.1
0.8	88.6	78.2	75.6	56.6
0.9	90.0	81.7	80.4	61.9
1.0	91.4	84.8	82.8	67.4
1.1	92.4	86.9	85.2	71.9
1.2	94.8	88.6	86.0	75.6
1.3	95.9	90.3	87.6	79.3
1.4	96.2	91.7	89.2	81.4
1.5	96.6	92.7	91.2	85.5
1.6	97.2	93.8	92.0	88.0
1.7	97.2	94.1	92.4	89.3
1.8	97.6	94.8	92.4	90.9
1.9	97.9	95.5	92.8	92.1
2.0	98.3	96.2	92.8	93.0
2.1	98.3	96.2	93.6	93.4
2.2	98.3	96.5	94.4	95.0
2.3	98.6	97.2	94.4	95.5
2.4	98.6	97.6	95.6	95.9
2.5	98.6	97.9	96.0	96.3
2.6	99.3	99.0	96.4	96.7
2.7	99.3	99.3	96.4	96.7
2.8	99.3	99.3	96.4	97.5
2.9	99.3	99.3	96.4	97.5
3.0	99.3	99.3	97.2	96.7
3.1	99.3	99.6	97.2	98.3
3.2	99.3	99.6	98.0	98.3
3.3	99.3	99.6	98.4	98.8
3.4	99.3	99.6	98.4	99.2
3.5	99.3	99.6	98.4	99.2

Table C4. Cumulative Frequency Distribution of Corn Samples, by Maximum BCFM Content and Origin of the Sample, Illinois, 1976 and 1977 Crops, 6/64-Inch Screen

Max. BCFM content, percent of weight	Country elevators		Terminal elevators	
	Receipts	Shipments	Receipts	Shipments
	percent of samples			
0.1	66.6	43.9	38.0	16.1
0.2	78.6	59.2	51.6	28.1
0.3	84.5	69.2	64.4	46.3
0.4	86.9	76.8	72.4	58.7
0.5	89.0	82.4	80.0	65.7
0.6	92.1	87.2	84.0	71.5
0.7	95.2	90.7	88.4	77.7
0.8	96.6	92.4	90.4	83.1
0.9	96.9	92.7	91.6	86.8
1.0	96.9	93.8	92.8	89.3
1.1	96.9	94.5	93.2	91.3
1.2	96.9	96.2	94.0	93.0
1.3	96.9	96.2	94.4	94.6
1.4	97.9	96.9	95.2	95.5
1.5	97.9	96.9	95.2	95.9
1.6	98.3	97.2	95.6	96.7
1.7	99.0	97.9	96.0	97.1
1.8	99.0	98.6	96.8	97.5
1.9	99.0	99.0	97.6	98.3
2.0	99.3	99.3	98.0	98.8